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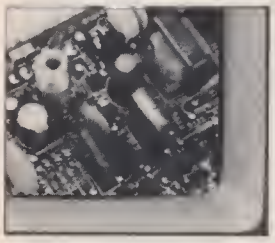

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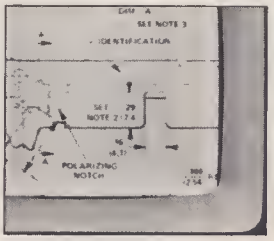

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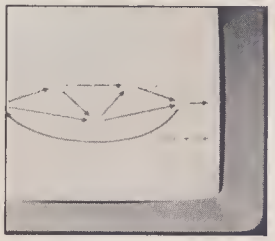

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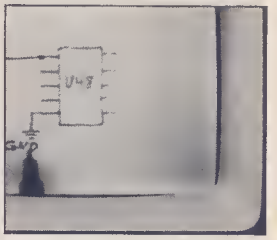

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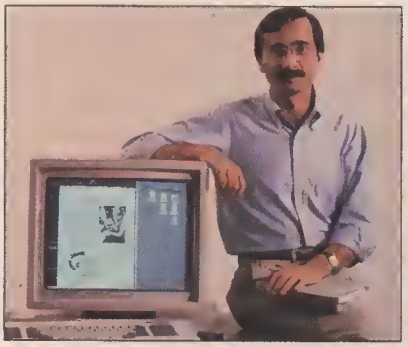

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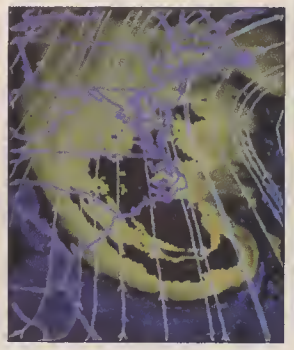

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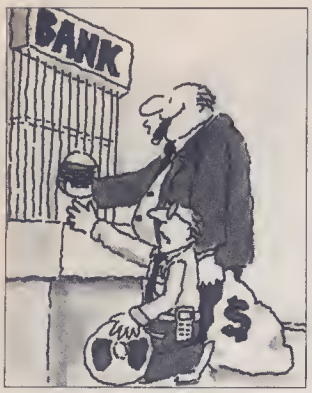

How to salvage the U.S. economy: Encourage saving, reward enterprise

To retain its economic strength in a rapidly changing global marketplace, the United States must modernize existing industries as well as create new ones. Both approaches call for large amounts of capital. Unfortunately, the cost of capital in the U.S. is very high, thus discouraging needed investments.

Some countries have national policies ensuring that favored, or sunrise, industries get the capital they need at very low interest rates. Here the opposite is true: Established industries generally pay the lowest rates, and new ventures, which are considered risky, pay the highest.

The United States is a consumption-oriented society that systematically rewards borrowers and penalizes savers. Until recently, banks were forced by law to pay artificially low interest rates to individual savers, and even this small return was taxed up to 50%. At the same time, the government paid up to 50% of the cost of a loan. Is it surprising that so many Americans borrowed much more than they saved?

Japan takes quite the opposite approach. Tax policies there encourage savings, and the savings rate is about five times that in the United States. Credit cards are almost nonexistent, and few loans are made to individuals. Banks lend money to businesses instead.

In the U.S., the President started his recent campaign to "reform" taxes by assuring the real estate industry that large deductions for property loans would be retained. The tax system provides excessive rewards for borrowers, and this is the basis for many tax shelter schemes. What's needed instead is greater incentives for saving, which would then increase the available capital. At the same time, the government should establish stronger incentives for industry to upgrade its plants and should make it easier for capital to flow into new enterprises.

That will take fresh thinking, perhaps using some ideas from other nations that are becoming much more competitive. In some countries, for example, businesses can build up a tax-free reserve in good times. Then, in a year when the economy slumps, the government permits industry to use these reserves for capital projects without paying taxes on them.

New policies shifting the U.S. away from a consumption bias would be unpopular and would require real leadership. But the alternative is a continuing erosion of established industries as other nations take away our markets.

Robert Haavind

Robert Haavind

SUSAN SMITH

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Satellite communications still riding high

I must take exception to your comment in "Making sense of the telecommunications circus" (Sept. 1985, p. 20) that "while satellite routes are acceptable for data transmissions, echoing and delay problems (which result from the time required for a signal to travel to and from a satellite) make this method a marginal solution for voice traffic."

Because advances in echo-cancellation technology have made satellite communications equal to or better than terrestrial facilities for the quality and clarity of com-

RICHARD J. FELDMANN

MAb producers are in business to find proprietary antibodies and "carve out unique proprietary niches for themselves."

Charles River Biotechnical Services (CRBS), the world's leading contract producer of monoclonal antibodies, has no such intentions. CRBS's unique strategy is to provide a full range of integrated bioprocessing services to biotech companies for large-scale manufacturing of MAbs and other recombinant cellular products.

Susan Michal Smith
Vice-President, Marketing
Charles River Biotechnical Services
Wilmington, Mass.

In your article "Micros at work" (Nov. 1985, p. 25), the name of my magazine was incorrectly referred to as *dBased Advisor*, instead of *Data Based Advisor*. dBase is a registered trademark of Ashton-Tate.

David M. Kalman, Editor-in-Chief
Data Based Advisor
San Diego, Cal.

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LETTERS

Star Wars wars

Bernard J. O'Keefe's common-sense insights about the Star Wars boondoggle ("Bringing 'Star Wars' down to earth," Feb. 1986, p. 8) will scarcely increase his welcome at the military-industrial feeding trough. I think Mr. O'Keefe is a true patriot. He puts national need ahead of corporate greed by speaking authoritatively about the futility of this grandiose Maginot-in-the-sky fantasy.

Our most urgent concern is economic competition, and our true adversary is Japan, not Russia. Perhaps, as Mr. O'Keefe suggests, the hidden agenda of Star Wars is to spend Russia into bankruptcy. But Mr. Gorbachev may choose to sit out this round of pointless expenditures, while Japan Inc. watches with satisfaction as we siphon our resources away from the competitive arena into never-never land.

Stanley Froud
Industrial Communications Associates
New York, N.Y.

I was happy to see that you devoted space to Bernard J. O'Keefe's viewpoint on Star Wars, despite your dedication to extolling high tech. Undoubtedly this program is technology of the highest order. Unfortunately, it is directed to the wrong ends and is unachievable in its originally stated form. And even if it were achieved, it would certainly not help the world situation.

Eugene V. Kosso
Verdi, Nev.

I subscribe to HIGH TECHNOLOGY because I want to keep up with scientific developments. When you publish such one-sided and biased political tripe on a subject like Star Wars that has strong arguments on both sides, I begin to wonder whether I am getting a balanced and objective report from the other articles in your magazine.

Henry Williams
Cincinnati, Ohio

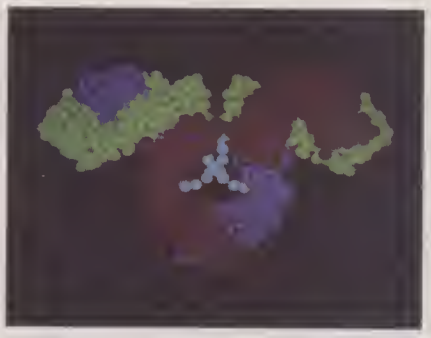
Satellite communications still riding high

I must take exception to your comment in "Making sense of the telecommunications circus" (Sept. 1985, p. 20) that "while satellite routes are acceptable for data transmissions, echoing and delay problems (which result from the time required for a signal to travel to and from a satellite) make this method a marginal solution for voice traffic."

Because advances in echo-cancellation technology have made satellite communications equal to or better than terrestrial facilities for the quality and clarity of communications, satellites have been the backbone of long-distance communications for the better part of a decade. Here in Canada, approximately 40–50% of all long-distance calls are routed by satellite, with the user having no perception of the medium used. The issue of delay has also been dealt with through this same technology: In most satellite systems today, the delay is imperceptible and is unnoticed by all but the most sensitive ears.

I agree that the introduction of fiber optics into telecommunications structures will impact satellites as a medium for heavy-route long-distance communications. But there are many other areas of communications where fiber is completely uneconomical due to geographical limitations, lack of traffic, the impracticality of fiber for temporary service, or simultaneous voice conferencing to multiple locations. Thus there will be a happy blend of copper, microwave, fiber, and satellites in the communications networks of the future.

Brand Miner, Product Manager
Satellite Communications
SED Systems
Saskatoon, Saskatchewan



Computer-drawn antibody. Some analysts foresee a MAb market of at least $1 billion by 1990.

Not all MAb producers want market niches

I read with interest your article "Monoclonal antibodies: promises fulfilled" (Feb. 1986, p. 32). The article is very thorough, but it is incorrect in its suggestion that all MAb producers are in business to find proprietary antibodies and "carve out unique proprietary niches for themselves."

Charles River Biotechnical Services (CRBS), the world's leading contract producer of monoclonal antibodies, has no such intentions. CRBS's unique strategy is to provide a full range of integrated bioprocessing services to biotech companies for large-scale manufacturing of MAbs and other recombinant cellular products.

Susan Michal Smith
Vice-President, Marketing
Charles River Biotechnical Services
Wilmington, Mass.

High tech law goes way back

The statement that "high tech law isn't a recognized specialty" in your article "Law firms focus on high tech" (Feb. 1986, p. 6) must have brought smiles to the faces of patent attorneys across America. Their specialty in technology-related law has been recognized by the American Bar Association for approximately 100 years, longer than any other legal specialty except admiralty law. Most of them practice in firms of intellectual-property specialists or in patent departments of large and medium-size corporations. They work on legal matters involving, for example, protection of software and technical drawings under copyright and trade-secret laws, biotechnology and supercomputer licensing, creation and protection of trademarks, litigation of issues involving theft of trade secrets and counterfeiting of products, and preparation of patent applications and patent litigation.

John B. Pegram, Esq.
Davis, Hoxie, Faithfull & Hapgood
New York, N.Y.

Crossed wires

I would like to offer some corrections to your article "Fiber optics simplifies auto wiring" (Feb. 1986, p. 7).

The 1987 STE 6000 steering-pad multiplex control system supplied by Packard Electric does not activate lights, power windows, and door locks. The system is a remote radio control head that controls 12 radio functions.

Furthermore, the data transmission from the steering pad to the instrument-panel-mounted radio head uses wires, except for an optical transmitter/receiver set in the mechanical slip ring. There are no optical fibers involved.

Jack Olin, Director
Advanced Engineering
Packard Electric Div., GM
Warren, Ohio

Well advised

In your article "Micros at work" (Nov. 1985, p. 25), the name of my magazine was incorrectly referred to as *dBased Advisor*, instead of *Data Based Advisor*. dBase is a registered trademark of Ashton-Tate.

David M. Kalman, Editor-in-Chief
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speak faster than words.

What you see here are some of the many, many words it would take to describe what's on the computer's screen. And even these aren't enough. Here's what we mean. Shown on the screen are five views of the Reduction Gear Housing Type GB-05B. Line drawings show a side elevation and two end elevations of the reduction gear. The side elevation shows the two line shaft housing castings and their relative size and position. The line shaft center lines are marked as broken lines. The line shaft housing castings are mounted on a two level fabricated plinth constructed of sheet metal. The reduction gear cover plate is also shown on this side elevation. The axes of the three gear wheels are shown on the top, bottom gears are mounted on extensions to the line shafts and the intermediate gear axis is shown as a broken line. The left hand end elevation gives additional detail of the construction of the two stage plinth and shows the general construction of the supports for the line shaft housing castings. The line shafts are positioned on a common vertical. The axis of the intermediate gear is shown and is positioned to the left of the line shaft centers; the gear cover plate is partially visible behind the plinth, and to accommodate the off-set intermediate gear, the gear cover plate has been angled from the vertical. The right hand end elevation shows further details to the gear cover plate—in particular, the circular ends of the cover which at the top is centered on the axis of the line shaft and at the bottom is centered on the axis of the intermediate gear. The axis for the two line shafts and the intermediate gear are clearly shown on the drawing with broken lines. The inclination of the gear cover to the vertical is defined by the position of the intermediate gear axis. Two isometric views of the gear reduction housing are shown. The first isometric view is a line drawing of the rear end of the housing. Some lines which are normally hidden are included which show the extent of the two stage plinth. The second isometric view is of the front end of the gear reduction housing. The drawing uses the colors red, yellow, blue and green to give an improved visualization of the object. The castings, plinth and gear cover are generally shown in yellow, horizontal surfaces are black, forward facing vertical surfaces are shown in red, and a red hatched pattern is used to show the top line shaft mounting.

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UPDATE

Aircraft firms vie for Air Force One contract

Within the next two months, the Air Force will determine which plane will harbor the aerial White House for the rest of this century. Officials from the Aeronautical Systems Division at Wright-Patterson AFB in Ohio are weighing two bids to build and equip the successors to Air Force One and Two, the Boeing 707-320s that have carried presidential parties for a total of 38 years.

The choice rests between the Douglas DC-10 and the Boeing 747—the only planes that meet the Air Force's fundamental specification of an aircraft with more than two engines, a cruising speed between 528 and 575 mph, a minimum range of 6000 nautical miles, and at least two years in commercial service. The more than 600 pages of requirements also specify the ability to carry 80 passengers and 23 crewmembers, and the flexibility to be outfitted with state-of-the-art secure communications systems, as well as a stateroom, a conference room, accommodation for the Secret Service, and a galley capable of serving at least 50 meals at a sitting.

The Air Force has budgeted about $300 million for the planes themselves and roughly $83 million for maintenance, service, and spare parts. It expects to take delivery of the new Air Force One in November 1988, with its companion to follow six months later.

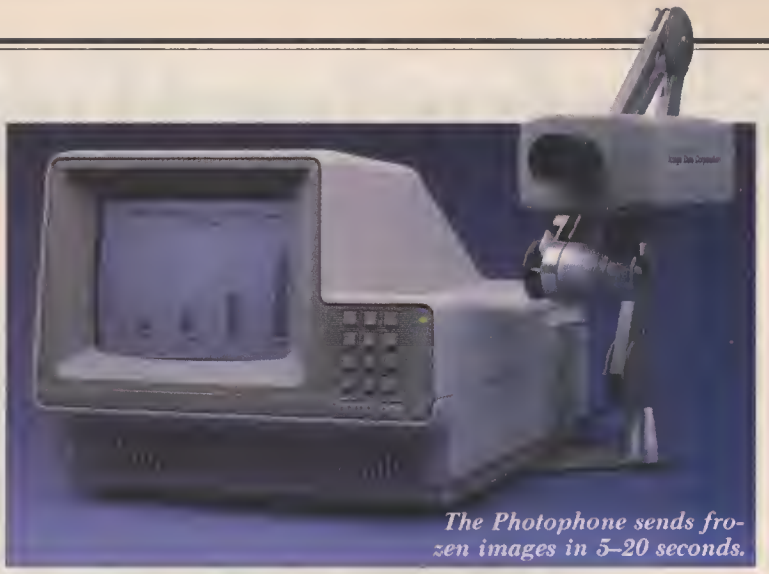
Drug implant attacks brain cancer

A slow-release drug delivery system that combines chemotherapy and biodegradable polymers holds promise as an effective weapon against brain tumors. The system, from Nova Pharmaceutical (Baltimore), consists of a polymer called a polyanhydride—developed at MIT—that is impregnated with an anticancer drug and implanted in the brain near the malignant site.

Tumors of the brain and central nervous system, which last year claimed more than 10,000 lives in the U.S., frequently defy conventional treatments. Surgery, for example, often fails because only a limited amount of tissue can be removed safely. And chemotherapy is often restricted by the "blood-brain barrier," which prevents many of the most effective anticancer drugs from reaching the nervous system. Even drugs that can be administered to the brain are often used in very small amounts to prevent toxic side effects.

In the Nova-MIT system, however, the tumor takes up virtually all of the drug as it seeps from the porous polymer matrix. As a result, concentrations can be used that are hundreds of times greater than with ordinary chemotherapy. The implant breaks down to biocompatible products within a few weeks.

According to Nova, clinical trials are scheduled to begin this spring at Johns Hopkins Medical School.



The Photophone sends frozen images in 5–20 seconds.

Phone sends pictures as well as voice

A desktop telephone outfitted with a video camera and a display screen permits users to talk and exchange still pictures over standard telephone lines. So far, about 300 of these Photophones have been sold by their developer, Image Data (San Antonio, Tex.), largely to companies that use them to transmit engineering drawings or images of actual products to distant locations. One customer, Atlantic Richfield (Los Angeles), transmits video images of hazardous sites at its Alaskan oil operations to company headquarters. In another application, radiologists in the Pacific Northwest exchange and discuss patients' x-rays.

The $8550 system plugs into a standard phone jack and uses proprietary algorithms to compress the data in each image by as much as 8:1. It then digitally transmits error-free video data at 9600 bits per second. Depending on the complexity of the picture, a transmission generally takes 5–20 seconds, during which time conversation is interrupted. With its 256K bytes of memory, the Photophone can store up to 30 pictures for future reference. In addition to being displayed on the system's nine-inch screen, images can be converted into paper copies by an optional printer or shown on large-screen video projectors. The Photophone also lets callers zoom in on areas of interest or point them out with on-screen arrows.

Stronger magnet allows smaller motors

Designers of small front-wheel-drive cars often have trouble squeezing the bulky starter motor under the hood. But starters appearing on some GM cars early this year will be just half the size and weight of their predecessors. That's because they will be using a superstrong permanent magnet called a Magnequench in place of the hefty coils or permanent magnets that line the casings of ordinary starter motors.

The magnet, developed by GM's Delco Remy division (Anderson, Ind.), is a compound of neodymium, iron, and boron. When this compound is rapidly cooled, or quenched, from the molten state, it forms a fine crystalline structure that leads to magnets 25% more powerful than samarium cobalt magnets, previously the strongest available.

The Delco starter motor, which contains six small magnets totaling about five ounces, is only the first application for Magnequench. The company hopes to sell the magnets for use in other electric motors, as well as tap the market for magnetic resonance scanners used in medical imaging.

Cars learn to listen

Although the day is still a long way off when you can drive a car just by saying "Home, James," some models will soon be able to respond to a few spoken commands. Votan, a speech recognition firm in Fremont, Cal., reports that it is supplying its technology—based on sound-wave-matching algorithms embedded on a microchip—to an undisclosed automaker, which will offer voice-operated controls as optional equipment on 1988 models. Verbal controls will be limited to functions that are nonessential but normally distracting to the driver, such as tuning the radio and adjusting temperature settings. One of the most likely uses, says VP Robert Russo, will be in dialing mobile telephones, which many states now prohibit drivers from doing while the car is moving.

Each driver will have to "train" the equipment to identify his or her voice and pronunciation patterns by repeating the words or phrases to be used as commands. But once this training is accomplished, it can be applied in fairly sophisticated ways. A particular voice saying "Set radio to rock music," for instance, becomes a command for tuning in a certain station.

Portable expert system helps a repairman test an air conditioner.

Maintenance expert in a briefcase

A briefcase-sized expert system is helping large commercial air conditioners keep their cool. Maintenance contractor Honeywell Building Services (Minneapolis) has begun using the expert system, known as Mentor, in which the know-how of seasoned repairmen is condensed into a body of facts and if/then rules that fit into the memory of a portable microcomputer. Developed by Honeywell's Technology Strategy Center, the system guides a technician through a routine maintenance check by posing a series of questions on, say, the pressure and temperature of coolant or the presence of unusual noises. If the reported conditions are out of line, the system steers its questions toward diagnosing and fixing the problem, meanwhile compiling a service record that the computer can refer to during subsequent checks on the same unit.

Honeywell expects Mentor to bring substantial savings—both by spotting trouble before it happens (thus reducing the frequency of repairs) and by permitting relatively inexperienced personnel to do the job. As a result, the company chops 40% off its service contract fee for buildings where Mentor is used. And air conditioners are only the beginning: A new "preventive maintenance language" developed for Mentor will be adapted for other building equipment as well, says marketing manager Robert Dickhaus.

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ST. LOUIS COUNTY ECONOMIC COUNCIL

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Stamping out waste in Washington

J. Peter Grace
Chairman and Chief Executive Officer
W. R. Grace & Co.

I have great misgivings about the future of our country's young entrepreneurs. The technologists working in Silicon Valley and on Route 128, for example, are among the most hard-working and innovative people in industry today. They deserve a future bright with promise. But that future will grow dimmer if Congress attempts to pay off its years of overspending with a flood of new taxes.

I believe that there are better alternatives. The President's Private Sector Survey on Cost Control, which I chaired, has offered a blueprint for government savings that contains 2478 specific recommendations to eliminate waste and inefficiency in the federal government. We estimated that these actions would save $424.4 billion over three years—without raising taxes, without weakening America's defenses, and without harming social welfare programs.

In the area of procurement, for example, we found the government's practices to be neither efficient nor cost-effective. They are hindered by excessive and inconsistent regulations, limited and inaccurate information, and poor and uncoordinated planning. Not only do they fail to take full advantage of private-sector competition, they create disincentives for acquiring goods and services at the lowest possible cost. We identified three-year savings of $34.5 billion in this area.

For example, our report suggested that both military and civilian agencies increase the practice of contracting out for commercial and industrial services. Many federal functions, such as maintenance and food provision, could be done by private companies at significant savings to the taxpayer.

At a more fundamental level, we proposed that incentives be created to reward efficiency and cost-cutting ideas. At present, federal managers' salaries are based on the size of their staffs and levels of spending. Why should they search for more efficient methods of operation?

We proposed ways to update the government's computers. Formerly the world's leader in automated data processing (ADP), the government now lags far behind the private sector. Despite the magnitude of federal computer operations, there is no system of ADP planning, procurement, or management. The average age of the government's computers is 6.7 years, or about twice the average for the private sector. Many computers are so old their manufacturers no longer service them. The added cost of maintaining a specially trained force of technicians to keep these automated dinosaurs running comes to roughly $1 billion over three years.

We made hundreds of recommendations to help the government improve its computer operations. We suggested bringing the total ADP inventory into line with private sector standards and developing a coherent system for ADP planning and management. Total savings possible in this area amount to $23 billion over three years.

Because there are few advocates of waste and inefficiency, most people in Washington are sympathetic to our recommendations—in principal. But in practice, almost 75% of the proposals must be approved by Congress—and, without outside pressure, that is where they will languish.

Congress talks of its willingness to eliminate unnecessary spending, but it seems quite unwilling to admit there is any; our representatives may be worried about our nation's economic future, but they are more immediately concerned about their political futures. They are less likely to ask whether an expenditure is necessary than whether it will get them reelected. Each congressman tries to send back home as big a slice of the federal pie as he can, and each fights to protect the special favors that blocs of voters have lobbied hard to secure.

As a result, congressional action and common sense are often at odds. For example, Congress prohibits the Department of Defense from soliciting competitive bids for the movement of household belongings between the mainland and Alaska and Hawaii, even though studies have shown that such competition could save $69.5 million over three years. This must benefit someone, but certainly not the 10,445 median families whose combined annual tax payments are wasted by this senseless prohibition. Similarly, Congress demands its approval for any personnel reorganizations affecting as few as three people in the Veteran's Administration—an agency with over 200,000 employees. Such actions may earn congressmen some votes, but they cost all taxpayers dearly.

That is how it goes in Washington. Billions of dollars being spent every day with little regard for efficiency. But we cannot continue inundating ourselves with all this unnecessary debt. More important, we cannot keep running up the tab for our children and grandchildren—an offense that amounts to taxation without representation.

The choices facing our country today are straightforward: Either "government as usual" or fiscal responsibility. Either short-term expediency or long-range planning. Either increased taxes or reduced federal spending. Congress must decide whether it is going to cut the heart out of the entrepreneur's budget—both at work and at home—or the fat out of its own. □

Mr. Grace recently helped form Citizens Against Government Waste to pursue his commission's recommendations. Further information may be obtained by calling (800) USA-DEBT.

BUSINESS STRATEGIES

Vista-United Telecom: BREAKING OUT OF THE MAGIC KINGDOM

When the late Walt Disney masterminded his futuristic Florida theme parks in the 1960s, his visions included state-of-the-art telecommunications. That's how Walt Disney World, which opened in 1971, came to have its own independent telephone company, a partnership between Walt Disney Productions—which kept a 51% controlling interest—and a regional phone company that later merged with what is now United Telephone of Florida.

Today, Vista-United Telecommunications, as the Lake Buena Vista (Fla.) firm is called, does more than provide telecommunications within the 28,000-acre Disney resort complex. When the industry was deregulated in 1981, Vista-United decided to take advantage of its reputation as a pioneer and sell systems, services, and advice to customers around the country. "We've gone national," says Joe Hegarty, the company's operations manager, "focusing on campus environments" such as hotels, hospitals, resorts, and universities.

The expansion program has already led to a more than doubling of revenues—$19 million for 1985, up from $8 million in 1980 (the last year before deregulation). "Vista-United is considered to be one of the most profitable local phone companies," says analyst Amy Francis of the Yankee Group, a Boston market research firm. "And it's viewed as very forward-looking and high tech." The company has sold or leased digital phone systems to area businesses such as Orlando International Airport, Sun Banks of Florida, Piedmont Airlines, Martin Marietta Data Systems, and Hilton Inns. It also consults for clients that include Ohio State University and the Mayo Clinic (Rochester, Minn.), runs answering and paging services, and provides satellite uplinks for broadcasts from Disney's Florida theme parks.

Vista-United earned its reputation as a technical groundbreaker by pulling off a number of industry firsts. For example, it was the first phone company to use fiber optic cable commercially. "Disney heard about fiber optics in the mid-1970s, when no one had yet put them in," recalls Hegarty. After performing its own feasibility tests, Vista-United installed a digital telephone system in 1978 that used fiber optics to connect more than 600 voice lines. The firm also introduced the country's first computer-controlled telephone operating center in the mid-1970s, complete with video-screen terminals for operators. And since last October, when it completed the upgrading of its switching equipment, Vista-United has proclaimed itself the world's first fully digital phone company. "Most companies are still trying to become 100% electronic," says Hegarty, referring to an industry still rife with mechanical switching gear.

The all-digital status applies to the 16,000-phone network on Disney property and to Vista-United's outside networks as well. These smaller systems are based on Northern Telecom's SL-1 private branch exchange, a digital switch with a capacity of several thousand lines. "We have 1200 lines and the capability of going to 3500," says George Walton of Martin Marietta Data Systems (Orlando, Fla.), a Vista-United customer for three years. In that time, "the whole system has never been down," he states.

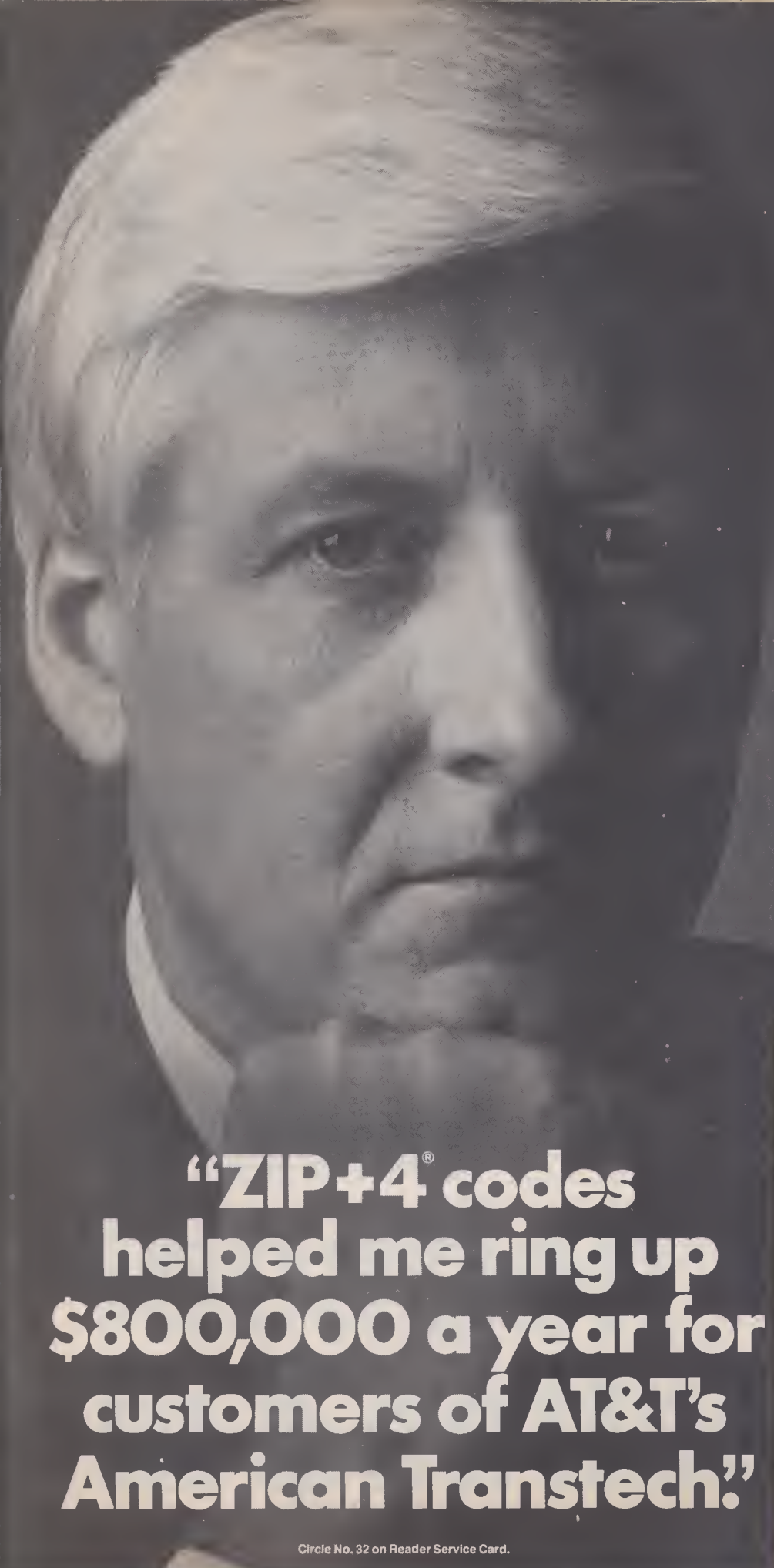
Despite having had to iron out bugs in innovative but sometimes unproven equipment, Vista-United maintains that its commitment to digital switching and fiber optics has made economic sense over the years. The cost of increasingly automated switching equipment has dropped substantially in the last decade, as has the price of optical fiber (falling from $2 a meter in 1978 to less than 50¢ today). Perhaps it was Walt Disney's penchant for total control that led to Vista-United's formation, but it was also Disney's fascination with technology that gave it a firm basis for becoming more than a Mickey Mouse operation. ***—Elizabeth Willson***

In one hand, Vista-United's Joe Hegarty holds the thin fiber optic cable his firm helped pioneer. In the other: conventional copper cable.

CRI: AIMING AT THE MILITARY SOFTWARE MARKET

In 1983, the Department of Defense (DOD) mandated that a single programming language be used to write software for all "mission critical" applications—essentially, all but those for ordinary office use. DOD was hoping to eliminate the software inconsistencies that can arise when as many as hundreds of programmers write mammoth defense programs. The language chosen was a new one called Ada, which is so highly structured that its very nature could help create uniformity.

An immediate problem, though, was that almost no one knew how to use Ada, and no library of backbone programs existed to help build large applications. Thus the Ada market has crawled along, with a handful of hardware and software vendors supplying little more than compilers—programs that enable the language to be used with various computers.



"It was easy," says Robert Turley. "I just convinced my company, American Transtech, that we could save over $800,000 a year in mailing costs by using ZIP + 4 codes, the Postal Service's computerized sorting system for First-Class Mail.

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CRI, a small, privately held company in Santa Clara, Cal., is trying to change this bleak picture. In January it began selling what it claims are two of the first commercial Ada applications in the U.S.: Relate/3000, a relational database management system, and ProjectAlert, a program designed to keep track of cost, labor, progress reports, and graphics for software development projects. It is betting that the packages will help it capture a chunk of DOD's budget for Ada, estimated by analyst John Frank of Input, a Rockville, Md., research firm, at $750 million in 1986 and $2.3 billion in 1990.

CRI's move into the Ada software realm, says Ronald Dumas, chief executive officer, has been "the best-kept secret in Silicon Valley." CRI began in 1971 as a financial management services company. When it later bought a Hewlett-Packard Model 3000 minicomputer, it decided to develop its own database management system because HP didn't supply one. CRI brought Relate to market in 1981 and, in 1983, introduced ProjectAlert. Today the programs are used by more than 200 government and corporate owners of Model 3000s, including the Navy and NASA.

But CRI soon realized that its continued growth could be stymied because much of its software was written in an HP proprietary programming language. To expand its market, CRI would have to rewrite the programs in a language that could run on many manufacturers' computers. At the time, "everyone else was looking at the C language," recalls Paul Fuller, VP for marketing and sales. C is the native language for Unix, a nonproprietary operating system from AT&T that was gaining popularity in the early 1980s. But when Digital Equipment, Data General, and IBM came out with slightly incompatible versions of C, it began to seem less suitable for gaining access to a broad market, says Fuller.

CRI instead turned to Ada, which was just starting to take its first struggling steps. Now, two years later, the growing Ada community is clamoring for database management systems. These complex programs are a vital part of many applications, and with Congress pressuring DOD to stop buying costly custom items, off-the-shelf Ada packages are in demand.

Hundreds of companies in the U.S. alone sell database management programs. "Any company involved in database management is probably looking into the Ada market," says Jerry Horsewood, president of AdaSoft (Lanham, Md.), another firm developing Ada programs. So far, however, only a few have actually entered that market. AdaSoft has introduced a small-scale Ada database management system and plans to bring out a large-scale version this year. Computer Corp. of America (Cambridge, Mass.), a contractor for the Defense Advanced Research Projects Agency, is working on a large-scale system. And TRW is studying database management along with the Army.

CRI hopes to capitalize on an early lead and is adding branch offices in Washington, D.C., Boston, Houston, Los Angeles, and San Francisco. (It already has one branch in the New York City area.) And the company plans to focus even more intently on the Ada market, says Dumas, which may require it to bring out new programs before long, as the database management niche gets more crowded. Whether CRI will find other niches for off-the-shelf software—when one-of-a-kind systems are the norm for defense projects—remains to be seen.

—Mary Jo Foley

Martin Marietta:

AEROSPACE FIRM FOCUSES ON DEFENSE

Less than four years has passed since Martin Marietta was fighting desperately to stem a hostile takeover attempt by Bendix. But since that time, the conglomerate has transformed itself into a leaner, less vulnerable organization that is more sharply focused on the military market. The company, based in Bethesda, Md., is plowing cash into weapons-technology R&D and bidding heavily for new government business. Martin is pursuing "long-term growth," according to Thomas Pownall, chairman and CEO, even at the risk of a temporary dip in earnings.

Martin had actually intended to trim its diverse holdings outside the aerospace and data-systems fields before the Bendix attack sidetracked it in 1982. But its response—buying enough Bendix stock to effect a counter-takeover and then selling it to Allied—took time and a great deal of money. Martin recovered by selling off valuable assets like its military-laser division and Florida real estate as well as lackluster ones such as cement and aluminum operations. In the process, it underwent a "complete metamorphosis," according to Moody's Investor Services, resulting in both renewed focus and $1 billion stripped from long-term debt.

Today, aerospace accounts for more than 80% of current revenues, up from 58% in 1981. And at the end of last year, Martin had a healthy order backlog of $9 billion. Indeed, only General Dynamics and Raytheon saw their defense business in 1985 grow faster.

With contracts spread throughout the armed services—including major responsibility for two Army missiles, an Air Force missile, and a night-vision system for Army and Navy helicopters—Martin depends on no single Pentagon program for more than 10% of total sales. It is also bidding heavily on projects for the Strategic Defense Initiative ("Star Wars") and has already garnered some $34 million in awards, according to estimates by the Federation of American Scientists.

But a frozen defense budget, expected to hover for the next few years at around $300 billion annually, could cloud the rosy picture. So could two government investigations of the company—a Pentagon probe into alleged cost mischarging, and a congressional inquiry into a possible violation of the Foreign Corrupt Practices Act, stemming from payments made by Martin and other defense companies to Korean officials. Although a lid on defense spending seems certain, it won't affect every program to the same degree, contends C. Douglas Lee, manager of institutional investments for the Washington Analysis Group. "When you look for places where there will be growth," he says, "Martin is there."

Another cloud on the horizon may be the uncertainty about the U.S. space program's immediate future in the wake of the recent Space Shuttle disaster. Martin is the second largest recipient of U.S. space money and a major NASA supplier; for example, the company makes the huge external fuel tank used in the shuttle's launch. While Martin will probably lose business from the postponement of shuttle launches, it stands to pick up additional long-term contracts if the government looks more favorably on using expendable rockets—such as Martin's Titan 34D missile—to launch satellites. *—Tim Smart*

East Kilbride has attracted more U.S. investment than any other location in Scotland.

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Although the US companies established in East Kilbride produce many products, they all make the same thing ultimately.

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Fiber optics: beyond 20,000,000,000 bits/sec.

Summary:

GTE scientists have demonstrated laser modulation and detection at rates as high as 20 gigabits/second. They have developed ultra-small lasers that have light emitting areas as small as 0.2 square microns. They are working to improve the glass fiber itself, as well as to produce optical analogs of electronic switches with the long-range goal of all-optical systems, in which message streams are switched as much as 10,000 times faster than at present.

GTE commercial involvement in fiber optics communications systems dates from the first such installation in Artesia, California, in 1977.

Our scientists developed the system's technology and equipment, and have been contributing to the state of the art ever since.

Current projects deal with increasing the capacity, the versatility, the applications of the systems; longer-term, we are exploring the possibility of all-optical systems.

Faster and faster...

Until recently, optical systems processed digital streams at speeds ranging up to hundreds of megabits per second.

Fast though that may seem, today's carriers are seeking speeds in the gigabits-per-second range. This might even permit the glass to be brought directly to satellite earth stations or microwave towers, for example, for direct conversion of radio signals to light.

Recently, GTE demonstrated the ability to turn diode lasers on and off at rates as high as 20 gigabits per second—about 333% higher than the greatest previously recorded speed.

...and smaller and smaller.

Such speeds require very special lasers. And, as you can see from the electron micrograph at upper right (the head of an ant looking at one of these lasers), it is extremely small.

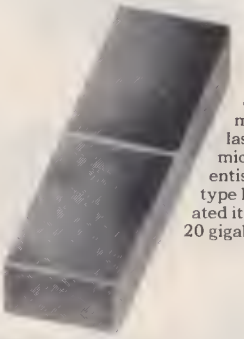
It was constructed on a wafer of InP, by epitaxial growth of a layer of InGaAsP approximately 0.1 micron thick. This was then etched to a mesa shape, and further layers of InP added.

The resulting laser cavity is approximately 0.2 square micron in area, and provides an excellent mate for single-mode glass fiber (fiber with a core of such small diameter that light travels a single path—mode—drastically lowering its dispersion within the fiber).

Switching light with light.

In another project, we are investigating the possibility of ultimately eliminating the electronics altogether by using optical switches.

We are working with materials whose indices of refraction vary with the intensity of incident light—a nonlinear response.



Head of an ant dwarfs a sub-micron-sized diode laser in this electron micrograph. GTE scientists developed this type laser, and have operated it at rates as high as 20 gigabits a second.

Ultimately, if it actually does become possible to switch systems optically, an improvement in speed of as much as 1,000,000% is theoretically possible.

In its brief history, fiber optics has made astonishing strides. At GTE, we are working to continue at the frontiers of this science—to make fiber optics an even more helpful technique to meet the endless needs of tomorrow's telecommunications.

The box lists some of the pertinent papers GTE people have published on various aspects of fiber optics. For any of these, you are invited to write GTE Marketing Services Center, Department FO, 70 Empire Drive, West Seneca, NY 14224.

Pertinent Papers

High Frequency Modulation on InGaAsP Lasers: R. Olshansky and C.B. Su, 5th International Conference on Integrated Optical Fibre Communications—11th European Conference on Optical Communications, Venice, Italy, October 1-4, 1985.

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GTE

BUSINESS TURNS TO IN-HOUSE PUBLISHING

With their own electronic workstations, companies can produce printed material faster and cheaper

by Dwight B. Davis

Over the past year, the technology of electronic publishing—also known as computer-aided publishing (CAP)—has begun to serve most of the hard-copy communications needs of hundreds of corporations. And this is only the beginning, says David Henry Goodstein, president of Inter-Consult (Cambridge, Mass.), a market research and consulting firm that tracks the electronic publishing market. In the U.S. alone, he maintains, more than 150,000 companies and government establishments are candidates for CAP systems, which help produce documentation ranging from insurance forms to product manuals. Ironically, far more pages are produced as an ancillary function of corporations and government agencies than by all the traditional book, magazine, and newspaper publishers combined. Xerox Systems Group (El Segundo, Cal.) reports that, in 1984, over 2.5 trillion pages of technical documentation were produced in the United States. And that represents just one CAP market sector, albeit the largest.

Until recently, only a few companies such as Boeing and Caterpillar Tractor recognized the extent and the cost of their activity in this area. "Boeing was spending about $2 billion each year on producing and distributing technical documentation," says Goodstein. But because in-house publishing is often fragmented throughout a company, most firms were doing a poor job of monitoring its costs. "Publishing might be a multimillion-dollar-a-year business at a company," he says, "but it's being bought out of 100 budgets and by 100 different managers." By developing cost-effective products that help automate and structure this activity—in response to the few companies that had identified their publishing costs—CAP system vendors have essentially created a whole new market.

Electronic publishing systems are not just a single technology: They meld computers, peripherals, and software. And they comprise everything from low-end systems that may be little more than sophisticated word-processing packages for personal computers, to advanced systems that let users merge text from word processors with graphics produced on computer-aided design (CAD) systems, compose the text and graphics into pages on high-resolution displays using different typefaces and layouts, and output the composed pages to laser printers or phototypesetters. Such high-end systems require considerable effort to build—the Technical Publishing System from Interleaf (Cambridge, Mass.), for example, contains more than 400,000 lines of software code—and they can cost from $50,000 to $100,000 and up, although the prices are dropping.

The spectrum of systems available reflects the wide range of CAP applications. A small company may use a PC-based system to produce little more than office reports and company newsletters (see "Page makeup for micros," p. 22), while a large aerospace firm that generates thousands of pages of technical documentation each year might require a system based on a mainframe computer or on many high-end workstations networked together. In the latter application, a CAP system's value may lie as much in its ability to handle and track multiple revisions over a decade's time as in its ability to compose text and graphics on a page. In addition, the system might have to support 10 or more people working on a single complex document simultaneously, producing text or graphics or composing the pages at networked terminals designed specifically for each task in the process. "We look at a document as a process, not as a hard product," says Alan Higginson, president of Caddex (Woodinville, Wash.), a high-end system vendor.

CAP genealogy. Magazine and newspaper publishers have relied heavily on electronic publishing systems of one sort or another for years. But these systems were so expensive and hard to use that corpora-

Market leader Interleaf recognizes that personal computers will soon offer the power of engineering workstations, says president Boucher. Thus the company will eventually sell its publishing software on PCs.

tions—even those that were engaged in major publishing activities—tended to shy away from them. The systems were also designed to address the requirements of periodical formats, frequencies, and production, all of which differ from those generally found in the world of corporate publishing.

As a result, corporate publishers typically turned to commercial typeshops, graphic designers, and printers to perform their composition and production tasks. Even at the commercial shops, however, the state-of-the-art CAP equipment left much to be desired. In composition and typesetting systems, for example, operators had to learn intricate codes in order to specify format and typefaces, the displays didn't present the layout and the fonts as they would appear when published, and the text

was output in straight columns that were manually cut and arranged into the proper format—along with any illustrations required—by paste-up artists. The complete pages would then be photographed to produce film negatives, which were then used to generate printing plates for producing the final hard copy. This process proved especially inefficient when revisions had to be made: Changes on one page in a document often required that many of the subsequent pages be torn up, repasted, and reshot.

In the early '80s, advances in composition systems permitted the operators to electronically paginate the text and to output formatted pages with "windows" left open for the manual insertion of artwork. But the latest systems—sold by start-up companies such as Interleaf, Caddex, Texet (Arlington, Mass.), and Xyvision (Woburn, Mass.), and by established vendors such as Xerox, Kodak (Rochester, N.Y.), and Compugraphic (Wilmington, Mass.)—permit varying degrees of text and graphic integration on screen. And they present an accurate image of a page's typeface, format, and illustrations on the display—a feature commonly known as WYSIWYG (what you see is what you get). WYSIWYG displays were made possible by the advent of high-resolution, bit-mapped screens: Because each dot, or pixel, on these displays can be individually turned on or off, the screens can display line drawings from CAD systems, halftone photographs that have been scanned and digitized, and text in different formats and fonts.

Magnifications of a halftone image and two type characters illustrate the difference in output quality between a 1000-line-per-inch phototypesetter and a 300-dot-per-inch laser printer.

SOURCE: INTERLEAF

Fully as important as WYSIWYG displays to the emergence of CAP has been the advent of laser printers that can print pages containing all the disparate elements displayed on the bit-mapped screens. With an average resolution of about 300 dots per inch (dpi), laser printers can't yet match the quality of phototypesetters (typically 1000–2000 lines per inch), but they are relatively inexpensive and much more flexible than computer printers based on earlier technologies. Laser printers enable users to obtain detailed page proofs that can be checked for errors before final output on phototypesetters, or may serve as the final printer for jobs that don't require typeset resolutions.

At their heart, CAP systems are sophisticated programs that tie laser printers, displays, and other peripherals together into a unified system. Not surprisingly, many of the early sales of the new systems have gone to commercial typeshops, the traditional market for such equipment. But thanks to their ease of use and falling hardware costs, the current crop of CAP systems—unlike their predecessors—are entering the corporate publishing market as well. The advantages of these new systems are hard to resist: Xyvision estimates that its customers have cut production times by as much as 68% and production costs by 30–50% per page. For a company heavily involved in publishing, such savings can cover the cost of a CAP system in less than a year.

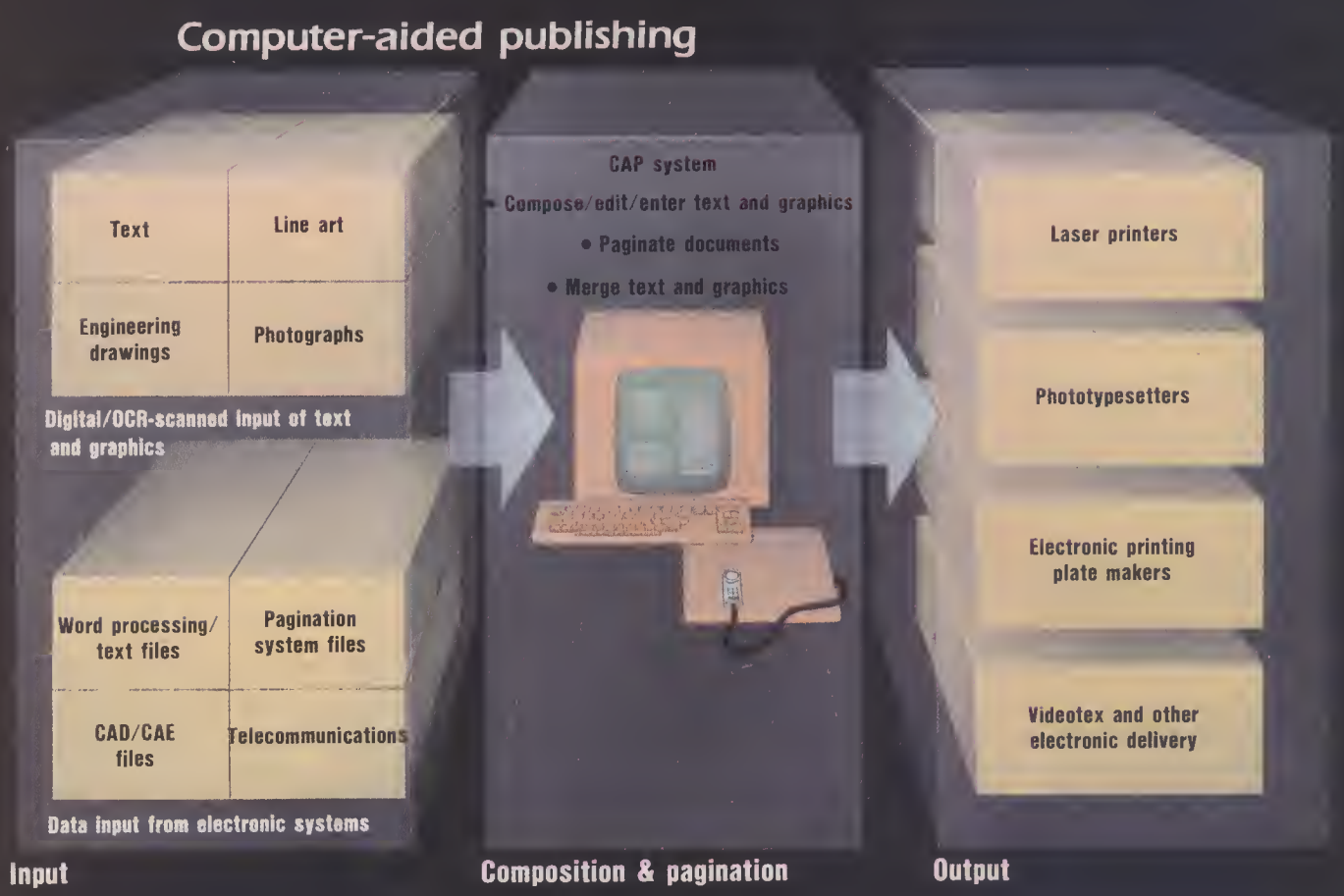
System distinctions. Underlying all CAP systems is a base of typographic and pagination features. Users want systems that can justify and center type, that can vary the amount of space between characters (kerning) and between lines (leading), and that can display typefaces on screen that closely match the fonts of a laser printer or a phototypesetter. "There is a list of 500 to 1000 desirable functions across various markets," says David Boucher, president of Interleaf.

One of the most important attributes of these advanced CAP systems is their ability to handle entire chapters or documents (as opposed to their predecessors' one-page-at-a-time routine). For example, if a user adds text on one page of a chapter using a system like the Interleaf TPS, the system will automatically "ripple through" any overflow material to each succeeding page. In less sophisticated, page-oriented products, the system has no "knowledge" about the preceding or following pages.

One high-end product, Texet's Live Image Publishing System, uses a tree-like structure to relate all the elements in a document; any revisions are automatically applied throughout the entire piece. If, for example, a user inserted a new section in a chapter, all the chapter's subsequent sections would be automatically renumbered. Thus section 3.4 might become section 3.5, and a reference in chapter 10 to a figure in section 3.4 would also be changed accordingly.

Automatic repagination and referencing make possible another key aspect of the newer systems: their interactivity. With WYSIWYG systems, users can change a subhead's typeface, shift from one to two columns of text, or move a photograph from the top of a page to the bottom, all on the system's display. They can make changes to a single page or can change the format of the entire document. And the ability to view the page electronically as changes are made helps ensure that the design is correct before the page is printed. By contrast, some CAP systems allow "batch" operation only, meaning that once the format and typestyle of a document are chosen, the document then runs off in its entirety.

Most of the high-end CAP systems maintain three separate databases: one for text files, one for graphics files, and one for format information. One advantage of this arrangement is that because the formatting codes aren't embedded in the text or graphics files, the files can be easily sent back to the word processor or CAD systems upon which they were created if revisions are required. A potential problem of keeping files separate is that the operator may have to change between text and graphics modes to modify one or the other, even though both are displayed on the WYSIWYG screen simultaneously. Most of the advanced systems, however, mask the file separation from users, permitting them to access the text or graphic material simply by placing the cursor over the relevant screen area.



CAP systems act as hubs that link and coordinate a variety of input and output devices. Systems vary in the types of peripherals they support and in their composition and pagination capabilities.

ILLUSTRATION BY MARK E. ALSOP, BASED ON XYVISION CHART

By providing separate files for format information, the CAP systems can be programmed with "libraries" of different formats. The user can pick a format from the library and apply it to bare text and graphics files to automatically generate documents with the appropriate typefaces and layouts. If unsatisfied with the results, the user can simply choose another standard format from the library.

Because the chosen formatting may not work on every page—a figure may not fit on the same page as its textual reference, for example—some of the advanced systems have a list of "try tables" that give a sequence of alternate formats. The system can automatically run through this list of format options—which can be ranked by preference—until it finds one that solves the problem. Or, rather than relying on the try tables, the user can interactively format the problem page as desired.

On several of the high-end CAP systems, the formatting and typestyle options are selected from English-language menus, similar to the pop-up menus popularized by the Apple Macintosh. This English-language interface is an important consideration for corporate users, who may have no desire to learn obscure coding to indicate format information or to establish a series of try tables. "On a lot of the earlier publishing systems, you almost had to be a programmer to set up the try tables," says Rebecca Marrs, marketing communications manager at Texet.

Not all the advanced-system suppliers have abandoned coding, however. Xyvision still requires that its users learn formatting codes, although the company is considering the addition of an English-language interface. "We're trying to achieve a balance between ease of training and ease of use," explains Philip C. Murray, manager of corporate communications at Xyvision. "If you're producing a moderately high volume of work, the Macintosh-type interface can get in the way: If you have to pull up a menu every time you want to perform some activity, it's far less efficient than typing in a couple of code characters."

Perhaps only factory automation poses more of an integration problem than CAP.

The new systems are also distinguished by their ability to compress the data received from scanners and other input devices. Because an $8\frac{1}{2} \times 11$–inch page scanned and digitized at 300 dots per inch requires about a megabyte of storage, and because transmitting this amount of data between different devices in a CAP system can take a prohibitively long time, each CAP vendor uses compression algorithms. Depending on the digitized material (a typewritten page can be compressed much more than a detailed halftone photograph) and the specific technique, compression ratios can range from 2:1 to 20:1. (If the algorithms leave out too much data, however, the reconstituted image may suffer in quality.) Although compression capabilities will remain critical to CAP systems, their importance is expected to diminish with the proliferation of high-capacity optical storage devices and fiber optic transmission links.

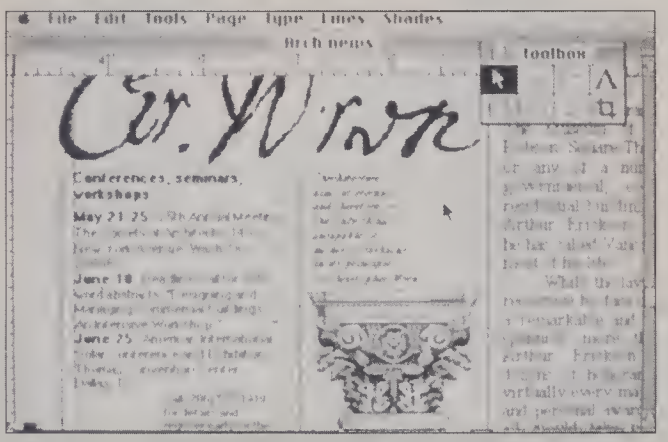
Features such as automatic pagina-

Page makeup programs for micros

Growing interest in page composition software has spawned many microcomputer products. But although developers have shown great ingenuity, current offerings provide neither the power nor the functionality of Interleaf and similar systems running on faster, more expensive hardware. The next round of microcomputer hardware will be able to run virtually any page makeup software now available, including Interleaf's, but for now users must compromise a little if they choose a micro-based system.

Page composition software ranges widely in price, from about $200 to over $10,000. Many software packages base their high price on the cost of the specialized front ends sold for typesetting equipment. These packages may include special features for specific typesetters and important capabilities such as hyphenation. However, the feature gap is closing much faster than the price gap.

The software packages also vary greatly in their ability to drive specific output devices. Many of the less expensive products do not drive traditional typesetters directly; instead they produce their output in the PostScript page description language. The same PostScript description can drive a fully graphics-capable laser printer for proofing and two Allied Linotype typesetters for finished copy, giving the user more flexibility than was provided by earlier equipment. The Allied typesetters are new, however, and PostScript thus far cannot be retrofitted to earlier equipment.



Running on an Apple Macintosh, Aldus's PageMaker software can create multipage documents containing text and graphics.

Page makeup programs fall roughly into three functional categories: markup languages, graphics-based without pictures, and graphics-based with pictures. Markup languages are the most common. With these the user embeds commands for typefaces and positioning in almost any word-processed document. It's not possible to see how the page will look until the instructions are processed and sent to a page printer or a typesetter (some programs can preview the output on a noninteractive screen display). Most markup languages cannot handle graphics, although a few let the user specify a location to place a graphic image. They are also hard to learn, but in some repetitive production applications—particularly text-only books with simple design and layout—markup languages can be quicker to use on present hardware than more sophisticated, graphics-oriented programs. This will probably change in the future as hardware gets faster; ultimately, everyone will work with a screen image that looks like the final output.

The new graphics-based software, being much simpler to learn and use, has attracted far more attention than the older markup languages. The Apple Macintosh has become the microcomputer of choice for page makeup applications, because its standard graphics format makes creating and exchanging graphics easy. Three programs can combine text and graphics freely on an interactive screen display as well as on the printed page. They can all create multipage documents and continue text from page to page. ReadySetGo ($200) is a simple, easy-to-learn program suited for straightforward tasks. MacPublisher ($200) and PageMaker ($500) deal more effectively with long text files and have more comprehensive layout tools. MacPublisher has such features as kerning (adjusting the spacing between letters for visual balance) and a transparent ruler on screen to help position page components. PageMaker accepts formatted files from both MacWrite and Microsoft Word, so text need not be reformatted. Some key features that have been lacking on the Macintosh products are now being met by new software such as MacHyphen and MacIndex for hyphenation and indexing.

Because the IBM PC lacks a standard graphics format, most PC products show less on screen than their Macintosh counterparts. However, two established packages employ a mouse-driven, bit-mapped screen to show pages like the Macintosh. SuperPage (about $7000), aimed at the typographic production house, has such features as job tracking and hyphenation and justification. But because it was conceived as a layout tool, it is not an efficient interactive editing system. Do-It ($2500–$3500) mimics traditional layout techniques, appealing to users familiar with stat cameras and T-squares. Users without such experience, however, may find the noninteractive design awkward and slow. A simplified version ($1400–$1700) can handle two pages at a time.

Forthcoming IBM PC products will probably encourage many more people to try their hand at desktop publishing. T/Maker's ClickArt Personal Publisher ($185 plus $150 for a laser printer driver) works so much like a Macintosh that it even uses Macintosh screen fonts and MacPaint graphics files; essentially the user creates graphic elements on a Mac and moves the file to an IBM PC. The ambitious Ventura Publisher ($700) runs under Digital Research's GEM interface and includes many production features intended to compete with dedicated typesetting systems.—***Cary Lu***

Companies

Aldus Corporation (PageMaker), 616 First Ave., Suite 400, Seattle, WA 98104, (206) 467–8165

Bestinfo (Superpage), 33 Chester Pike, Ridley Park, PA 19078, (215) 521-0757

Boston Software Publishers (MacPublisher II, MacHyphen, MacIndex), 1260 Boylston St., Boston, MA 02215, (617) 267–4747

Knowledge Engineering (JustText), GPO Box 2139, New York, NY 10116, (212) 473–0095

Manhattan Graphics (ReadySetGo), 163 Varick St., New York, NY 10013, (212) 924–2778

Studio Software Corp. (Do-it), 17862-C Fitch, Irvine CA 92714, (714) 474-0131

T/Maker (ClickArt), 2115 Landings Dr., Mountain View, CA 94043, (415) 962-0195

Ventura Software (Ventura Publisher), 675 Jarvis Dr., Suite C, Morgan Hill, CA 95037, (408) 779–5000

tion and compression are indeed valuable, but high-end systems must often work in environments where production capabilities are not of primary importance. Production accounts for only 10% of the total documentation cost in the technical publishing market, according to Caddex, while research and creation of the document account for 55% and system management and support make up 35%. As a result, systems that address only the typographic and production aspects of publishing may improve the efficiency of the overall process only slightly, says Caddex president Higginson.

Systems that go beyond the basic publishing functions allow multiple revisions, provide access for distributed authors and editors, and maintain close links to existing text and graphics databases. A CAP system from Context (Beaverton, Ore.) offers such expanded capabilities because it was developed to fit smoothly into the the computer-aided engineering (CAE) environment, says Michael Bosworth, the company's president. Context is a spinoff of CAE vendor Mentor Graphics, and its CAP system is based on documentation software originally developed as an optional module for Mentor's engineering customers.

CAP systems can substantially shorten the portion of a design cycle—traditionally about 30%—spent on documentation.

ILLUSTRATION BY MARK E. ALSOP; SOURCES: HEWLETT-PACKARD & MENTOR GRAPHICS

Electronic hubs. The full spectrum of computer-aided publishing systems can, of course, vary considerably in price and power, but they all encompass three basic functions: text and graphics input, editing and composition, and output. The best of the products can be thought of as electronic hubs that coordinate and manage a wide variety of devices, corralling them all into a single, unified system.

While the use of graphics material in corporate publishing is growing, text still dominates most applications. Most corporations are already using dedicated word processors or PC-based word-processing software to generate textual material; thus the ability for CAP systems to accept input from installed word-processing systems is a key attribute. "The number-one requested interface for our system is to [the PC-based program] WordStar," says Interleaf's Boucher, "followed by an interface for Wang word processors."

Many CAP systems also accept input from devices such as hard-copy scanners, optical character recognition (OCR) systems, CAD systems, and facsimile transmissions. As with the word processors, some companies may already own such equipment and want to enhance its value by linking it to a CAP system. Others may choose to acquire new types of input devices when they buy the publishing system, an option that becomes more attractive with the improving price/performance of the peripherals.

Digital scanners, for instance, typically scan and digitize hard copy—text and graphics—at resolutions of 200–300 dpi and cost $3000–$6000. Over the next two years, the average resolution of these devices will reach 400 dpi and their price will fall to $500–$3000, according to James McNaul, VP of marketing and planning for Datacopy (Mountain View, Cal.), a vendor of scanners, laser printers, and PC-based publishing software. He also predicts that, over the same period, OCR devices will drop in price from $5000–$15,000 to $3000–$7500 and go from reading only a few fixed fonts to reading a wide range of typefaces.

On the output side, it is expected that the resolution of laser printers will steadily improve. "Within five years we may compete directly with phototypesetters," says Pat Welch, president of laser printer manufacturer Imagen (Mountain View, Cal.). Other printing technologies such as ion deposition may also come into play. Ion deposition printers, which generate ions that adhere to a dielectric print drum and, in turn, attract oppositely charged toner, have fewer moving parts than laser printers, which charge a photosensitive print drum and then use a laser's light to selectively eliminate the charge prior to the application of toner. Ion deposition printers tend to have slightly lower resolution than equivalently priced laser printers, but they have the potential to displace them, claims Gary Sharpe, president and CEO of Delphax (Westwood, Mass.), because they are simpler, cleaner, and faster than the laser mechanisms.

The bulk of CAP applications and systems are geared to hard-copy output on printers or phototypesetters, but this may not always be the case. Corporations will turn increasingly to alternate modes of publishing their material, including the electronic transmission of computer-based videotex pages and the distribution of documents on optical discs or micrographic film. Most CAP systems are only gradually moving to support such multimedia output, however, because the demand for paper documents still predominates.

In between the input and the output devices are the computers and displays that manage the whole process and support the editing and composition activities. CAP systems are sold either as software packages that run on a customer's in-house computers or as turnkey systems, which come complete with hardware and software. While some software is sold to operate on mainframe computers and their associated "dumb" terminals, most of the latest CAP systems are designed to work with either personal computers or microprocessor-based engineering workstations such as those sold by Apollo, Sun Microsystems, and Digital Equipment. Some

BUSINESS OUTLOOK

Electronic publishing heads for high growth

Electronic publishing systems have emerged as important tools for reducing the time and cost of publishing a wide range of material. But because of the variety of products that may be incorporated into such systems—including micro and mainframe computers, laser printers, phototypesetting equipment, and software that integrates these elements—estimates of the market for electronic publishing vary widely. Perhaps the broadest estimate is provided by InterConsult (Cambridge, Mass.), which forecasts 1985 revenues at $5.5 billion, growing to $50 billion by 1990; sales of turnkey systems and individually sold components are included in these figures. Analysts generally agree that growth rates in most market segments will be 30–50% annually.

Three major segments make up this market. The most elaborate and expensive systems tend to be used for high-volume, text-intensive production of newspapers, catalogs, and magazines. Such systems, which may incorporate several hundred terminals under the control of a mainframe, provide a high level of automation for text entry, page makeup, and copy flow. "This is a relatively mature and expensive part of the market," says Jonathan Seybold, editor of *The Seybold Report on Publishing Systems* (Malibu, Cal.). "Automating the entire production process can cost several million dollars."

Given the limited number of potential customers and the high cost of developing such equipment, relatively few vendors offer fully integrated production publishing systems. The leaders include Kodak's Atex Division (Bedford, Mass.) and Systems Integrators (Sacramento).

Another major market is corporate publishing, which has posted the largest growth gains in the electronic publishing arena. Major applications include the production of technical documents, in-house graphic arts, and a variety of office-related publications. Systems are usually based on powerful 32-bit, bit-mapped workstations and minicomputers—such as those from Sun Microsystems (Mountain View, Cal.), Apollo Computer (Chelmsford, Mass.), and Digital Equipment (Maynard, Mass.), linked with laser printers; such systems cost $50,000–$300,000. They allow several individuals to work on the same document and are especially useful for integrating text and graphics. These systems also produce "what you see is what you get" (WYSIWYG) screen displays that preview the exact appearance of a published document.

"We anticipate that within the next few years, most corporate documents that are now being sent to outside typesetting shops will be produced internally using electronic publishing systems."

Kenneth Abbott
President
Manhattan Graphics

The growth potential for this market is high, says David Henry Goodstein, president of InterConsult, because "large corporations typically spend 6–10% of their gross revenues on various kinds of paper-based communications." And much of this material—about 70%—is "well suited to publication by corporate-based systems," says Robert V. Adams, president of Xerox Systems Group (El Segundo, Cal.), because it contains a mix of elements, including text, data, drawings, and graphs.

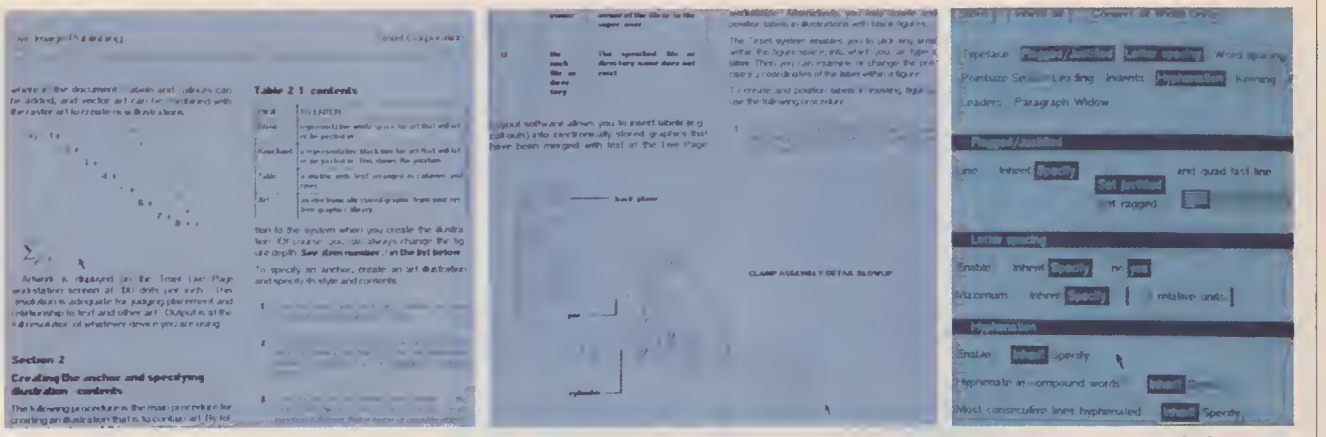
The current front-runner is Interleaf (Cambridge, Mass.); other important vendors include Xyvision (Woburn, Mass.) and Texet (Arlington, Mass.). Several major computer and reprographics companies—including Xerox, Kodak (Rochester, N.Y.), and Digital Equipment—have recently entered this market and may attract customers who might be reluctant to deal with smaller suppliers.

The third segment comprises microcomputer-based, single-user desktop systems. Like larger corporate systems, this equipment is found mainly in businesses and may have WYSIWYG features; however, desktop systems are typically used for smaller jobs such as short reports, news releases, newsletters, and office forms. Seybold maintains that the performance gap between personal computer systems and more expensive workstations will narrow considerably over the next few years, as PCs take on more sophisticated tasks.

Costing under $10,000, a desktop system usually combines an Apple Macintosh or IBM PC with a laser printer and specialized software such as PageMaker from Aldus (Seattle), MacPublisher from Boston Software Publishers (Boston), and ReadySetGo from Manhattan Graphics (New York). Sales of desktop software and peripherals should climb rapidly, from $100 million in 1985 to $1 billion by 1990, making this the fastest-growing market segment in electronic publishing, according to Creative Strategies Research International (San Jose).

Electronic publishing systems should continue to grow because "publishing is one of the last bastions of labor-intensive work," says Jose Ramos, editor of *WYSIWYG* (Redwood City, Cal.), a market newsletter. "Virtually any form of automation still yields a conspicuous payoff when compared to conventional cut-and-paste methods." Moreover, companies whose publications require numerous revisions, such as product documentation, price lists, and executive-level financial and marketing presentations, may particularly benefit from electronic publishing. "Our customers report that each page of a technical document goes through an average of 13 revisions during its life cycle," says Steven Schwartz, VP of corporate communications at Interleaf. "By bringing such applications in-house, firms not only save time, but may gain better control over publication schedules and product quality." ***—Jeffrey Tarter***

RAY ELLIS



Publishing systems such as Texet's let users choose formatting instructions from menus (right) to configure pages with diverse elements such as mathematical symbols, line drawings, and different typefaces.

of the high-end CAP vendors—including Xyvision and Texet—produce their own proprietary workstations to run their publishing software.

Editing/composing terminals vary considerably in screen resolution. The Apple Macintosh has a resolution of 72 dpi, the high-end workstations run about 80 dpi, and the proprietary systems achieve about 100 dpi. The higher the resolution, the more closely the displayed page matches the final text and graphics output—300 dpi on a typical laser printer. But it is generally believed that pushing up the screen resolution reaches a point of diminishing returns around 100 dpi, where the cost of improvements isn't worth the visual enhancements.

Even more important than screen resolution is the power of the underlying computer. All the high-end WYSIWYG systems run on workstations that incorporate 32-bit microprocessors and large internal memories. This capacity permits the systems to support the massive software programs required for advanced CAP functions and to run them faster than personal computers or terminals linked to mainframes. But these distinctions are rapidly fading. "Two years from now, I really don't believe there will be any difference between a low-end workstation and a PC," says Paul Needham, director of marketing at Context. "And we firmly believe that the solution will be on general-purpose machines—be they PCs or workstations—not on proprietary hardware."

But if CAP systems required no more than powerful computers, high-resolution displays, and various input and output devices, building such systems would be a simple matter. The hard part comes when vendors attempt to link these elements and to produce software that meets the editing, pagination, and composition needs of corporate publishers. Perhaps only factory automation poses more of an integration problem.

CAP systems can easily accept information from word processors as standard ASCII code, the 7-bit binary representation of characters and numerals. But ASCII doesn't encompass formatting or typestyle information. Thus, if a writer using WordStar or some other word-processing program centers a column and creates a boldface subhead, this format is lost when the file is converted to ASCII for transmission to the CAP system. To preserve such format information, the CAP software must recognize and correctly translate the code for that particular word processor.

The case of graphics is even more complex. Graphics input can be in the form of a constant stream of on/off bits from a digitizing scanner, it can come from sophisticated CAD systems, or it can be generated by graphics software packages. The data from each of these types of sources vary in their arrangement and content, and even data from within each type—say, from two different brands of CAD systems—can vary considerably in how graphic images are encoded. Standards are beginning to ease these problems, but they have a long way to go. For example, much

Context president Bosworth predicts that the company will prosper because of its access to the CAE marketplace through parent company Mentor Graphics.

A key to success for CAP systems in the technical documentation field, says Caddex president Higginson, is the ability to easily handle multiple revisions.

work has gone into what is called the Initial Graphic Exchange Standard (IGES), designed to allow the exchange of drawings between different CAD systems (or, in this case, between a CAD system and a CAP system). Many CAP suppliers say their systems support the IGES standard, but as Context's Needham observes, "standards are a moving target. If someone says 'IGES support,' he may be talking about three different chronological snapshots."

On the output side, probably the most important development has been that of page description languages, which take the data that describe the makeup of a formatted page and convert them into commands that drive the output devices. By running a common page description language, users can ensure that a page produced on, say, a laser printer will be identical to the same page generated on a phototypesetter, aside from the differences in resolution. The most successful of these languages is PostScript from Adobe Systems (Palo Alto, Cal.); its closest (but still distant) competitor is Xerox's Interpress.

Market evolution. Standards will gel slowly, but the CAP market will change rapidly, both technically and in terms of its major players. The start-up companies that have so far driven the technology will have to retrench as larger, more established companies enter the market. And all the vendors will have to work hard on software to differentiate their products, since all CAP systems are likely to run on similar, and often identical, hardware.

Already, companies like Texet and Xyvision, which base much of their marketing strategy on powerful, proprietary workstations, are also moving to provide their CAP software on standard engineering workstations such as those from Apollo, Sun, and DEC. Both Texet and Xyvision maintain that their proprietary workstations continue to give them advantages over the competition by offering more computing power and by providing higher resolutions than the general-purpose machines. But they also recognize the market's demand for software that runs on standard hardware.

"We look at documentation as a process, not as a hard product."

What's more, pressure on the high-end CAP vendors will increase from below, as personal computers begin to match the power and resolution of the engineering workstations. Most CAP vendors claim to be prepared for that eventuality, and some even say the current distinctions are as much semantic as technical. "We're already in the PC business in a certain sense," says Interleaf's Boucher, even though the company's software currently runs only on hardware from the major workstation vendors. "It just happens that engineers get really nice PCs compared to the world at large."

Most of the high-end CAP vendors today sell turnkey systems directly to their customers, but with the blurring of hardware distinctions it's likely that their sales will increasingly be software only. Electronic publishing still sometimes requires enough computing power to justify the purchase of dedicated hardware to run the application. But CAP will increasingly go the way of word processing, which started out on dedicated hardware and became just one of many software applications for multipurpose computers. Interleaf attained its CAP market leadership in part because it recognized this principle early on, and sold software licenses as well as turnkey systems from the start.

CAP's trend toward becoming primarily a software product may favor some of the major hardware vendors that are moving to enter the field. Computer companies such as Xerox, DEC, and IBM, with large installed bases of machines, are in a strong position to offer their customers CAP software for their existing equipment. Likewise, CAD and CAE suppliers such as Computervision (Bedford, Mass.) and Mentor Graphics (via spinoff Context) hope to do well selling publishing software to their user bases.

The strategy of some independent CAP vendors is to forge relationships with these firms. Interleaf, for example, licenses its software to DEC and Kodak, among others. It also has an agreement with IBM, which will market Interleaf's software as one of the applications available on the RT Personal Computer, IBM's entrée into the engineering workstation marketplace. This strategy reflects Interleaf's vision of how the industry will evolve. Despite the early lead of Interleaf and other start-up CAP vendors, there will be "a tremendous market shakeout," predicts Boucher. "Major companies will be the dominant forces in the market." □

Dwight B. Davis is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*

Tomorrow's weather: NEW ACCURACY IN FORECASTING

Better observation methods will make routine predictions more accurate and speed the detection of hazards such as tornadoes and wind shear

by Gordon Graff

Even in this age of satellites and computers, weather prediction sometimes leaves a lot to be desired. While the science has gradually become more accurate—today's five-day forecasts are said to be as reliable as the 36-hour forecasts of 1950—it is still clouded by inadequate observation and computing power. Now legions of meteorologists, physicists, and instrument makers, using tools ranging from advanced "doppler" radars to laser-based remote sensors and supercomputers, are trying to take the guesswork out of forecasting. Within a decade, their efforts may greatly boost the accuracy of short- and long-range forecasts. For example:

- Highly specific forecasts will enable people to find out the chances of rain or snow in their immediate neighborhoods between, say, two and three o'clock the following afternoon.
- Tornado warnings will be possible 20 minutes in advance, instead of after a sighting, as is common today.
- Weather conditions at airports will be checked continuously by automatic instruments instead of hourly by human observers, and it will be possible to monitor hazards such as wind shear, which defy accurate measurement today.
- The reliability of monthly forecasts will increase significantly, allowing utilities, oil refiners, and other businesses to make firmer production plans.

Aside from providing valuable information, these new

Sheltered in the dome is NOAA's doppler radar, which can measure wind speed in distant storms.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

WEATHER PHOTOS: STOCK IMAGERY

forecasting capabilities will offer lucrative business opportunities. "There's a lot of money to be made" in packaging the new highly specific weather information for individual subscribers, says Alexander E. MacDonald, director of the federal government's Program for Regional Observing and Forecasting Services (PROFS), which is now developing the technology for such forecasts. Also benefiting will be the makers of laser sensing devices, new radar systems, lightning and wind shear detectors, and other advanced equipment that will be used by meteorologists, forestry officials, power companies, and airports.

BRUCE MCALLISTER

PROFS' MacDonald studies data used in making highly specific localized forecasts. New readings come in every 10 seconds.

Historically, two of the biggest barriers to better weather forecasts have been an insufficiency of atmospheric data for local regions and the inability to process the available data fast enough. But automatic measurement systems and faster computers are rapidly changing things. At the PROFS project, which is run by the National Oceanic and Atmospheric Administration (NOAA) office in Boulder, Colo., both technological developments are being combined to provide "mesoscale" forecasts, which cover a limited geographical region such as a city. By contrast, the National Weather Service (NWS), an arm of NOAA, now typically issues "synoptic-scale" reports for regions consisting of one or more states. Ordinarily, the Weather Service's National Meteorological Center in Camp Springs, Md., sends out its synoptic forecasts every 12 hours to each of its 52 forecast offices and 150 service offices. These predictions are based on data from a vast array of surface, satellite, and airborne instruments. Updated data taken hourly, or sometimes half-hourly, are also available to the regional offices. But even with updating, the synoptic forecasts may miss certain transient or highly local weather phenomena such as scattered thunderstorms. Thus the first aim of the PROFS project, which began in 1980, has been to fill in the data gaps in the conventional forecasting system.

The PROFS test area is a region about 125 miles in diameter centered at Boulder. Twenty-two ground-based automated weather stations have been scattered throughout the region. At each station instruments measure conditions such as wind speed and direction, temperature, pressure, dew point, and solar radiation; every 10 seconds a microprocessor transmits the data from the sensors to the central facility in Boulder. This network is supplemented by several radar and lightning-detection systems placed at strategic points in the test area, as well as by data from NOAA's Geostationary Operational Environmental Satellite (GOES). In addition, PROFS receives data from the Federal Aviation Administration (FAA) on surface and upper-air weather for the entire western U.S.

The resulting mass of data is sorted out by computer and presented in the

Lightning detectors warn of danger on the way

Lightning kills scores of people every year and causes staggering economic losses from forest fires and electrical power outages. As a result, forestry officials and electric utilities are increasingly seeking early warning systems, particularly for the dangerous cloud-to-ground strokes. Knowing where trouble may strike helps these organizations plan responses well in advance. That's the idea behind a detection system marketed by a Tucson, Ariz., company called Lightning Location and Protection (LLP). The instrument senses lightning up to 200 miles away by exploiting a phenomenon familiar to anyone who has ever played a radio or television during an electrical storm: the static-producing radio waves given off by a lightning bolt.

A cloud-to-ground discharge begins with a feeble leader stroke followed by a return stroke with a power of up to 20,000 megawatts, far stronger than any man-made radio transmitter. The low-frequency radio waves emitted by the return strokes have a characteristic shape that triggers a warning signal from the LLP device.

The unit's sensors consist of two perpendicular loop antennas, one of which points due north. The relative strength of the radio signal in both loops tells the angle, relative to the north–south axis, at which the discharge occurred. The data on signal strengths and directions are digitized by the system's microprocessor and sent over telephone lines to a central receiving station. When two or more sensors detect the same lightning flash, a computer can use the known distance between the sensors and the angles at which the discharge occurred to triangulate its exact coordinates. A high-resolution color screen shows the locations of current and recent lightning flashes superimposed on a background map. Each stroke is color-coded according to how recently it hit.

Right now, LLP's biggest customers are forest-fire control agencies. But electric utilities, which rank second, "are potentially the largest user base we have," says LLP product marketing manager Michael Maier. Another important outlet for LLP's products is research efforts, such as the federal government's Program for Regional Observing and Forecasting Services (PROFS) and Airport Weather Observing System (AWOS) program. In addition, lightning sensors help forecasters at National Weather Service offices in Albany and Salt Lake City distinguish between ordinary showers and thunderstorms, which can look the same on radar.

form of two types of displays: color-enhanced images derived from radar or satellite cameras, and graphics indicating temperature, dew points, and wind speed and direction at each of the 22 stations. The displays can be mixed and matched to, for example, overlay radar images on a plot of the observing stations. Since these displays are available virtually in real time, meteorologists can follow the movement of storm cells right on the screen and can extrapolate where the storms are heading. This enables them to issue warnings of severe local storms up to 30 minutes in advance.

Although still experimental, the PROFS system has already achieved an impressive track record, says MacDonald. He cites recent comparisons of the "critical success ratios" (percentages of forecasts that turn out to be correct) for severe storm warnings issued by PROFS and those made routinely by NWS. In 1983, he says, the NWS ratio for the Denver area was about 20%, while the PROFS ratio was 30%. Significantly, he adds, the PROFS test area was less than half the size of NWS's. "We had a contest of darts where they had a bigger target and we still beat them," boasts MacDonald.

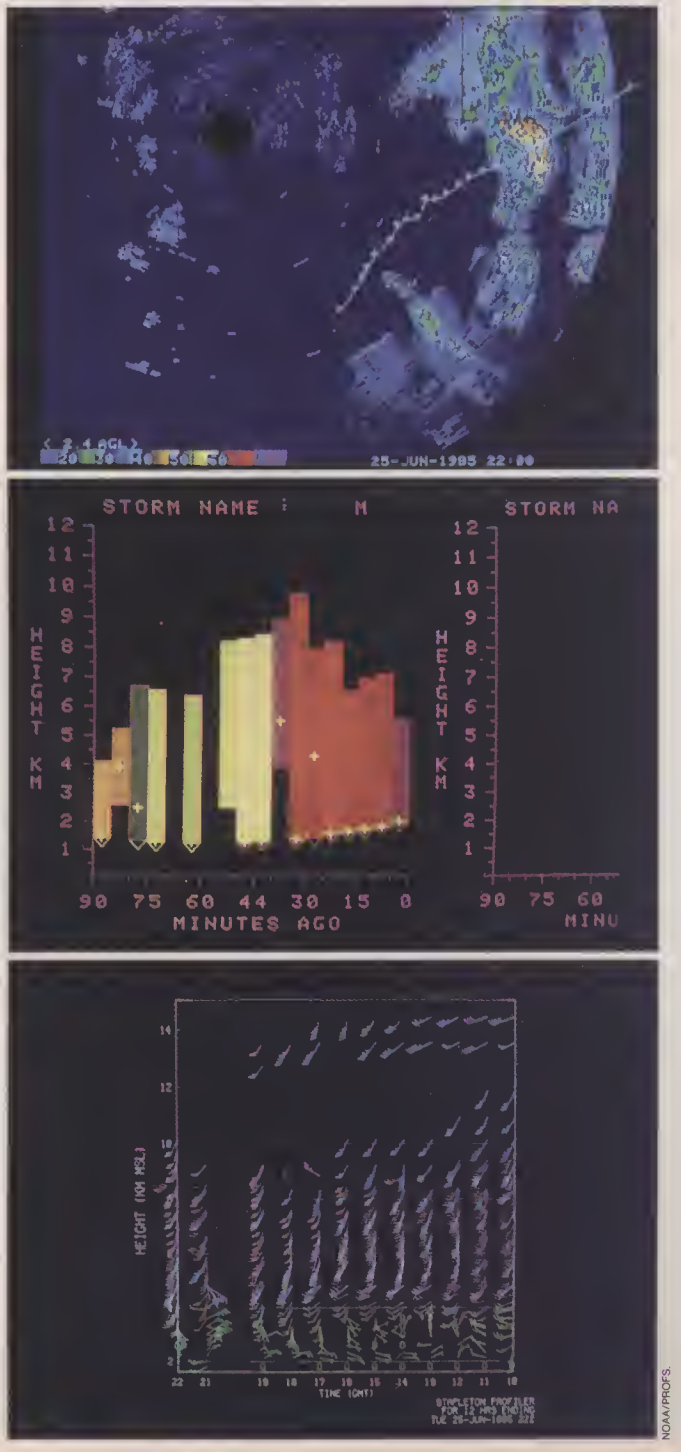
Not to be outdone, the NWS has plans to deploy 113 short-range forecasting systems very similar to PROFS all around the country in the 1990s. These systems will include the same high data density and capabilities for real-time tracking over a small geographical area. The net result should be a dramatic improvement in the accuracy and geographical specificity of weather prediction, particularly for 12-hour forecasts. New York City residents, for example, will be able to get reliable predictions on whether it will rain in Central Park during the next four hours, and they'll be able to get updates every hour.

But how will people obtain such tailor-made forecasts? Certainly not on radio or television news programs, where weather reports typically occupy only a few minutes. Instead, MacDonald foresees commercial databases such as Compuserve or the Dow Jones News Service making this NWS information available to subscribers with computer terminals.

The PROFS-type systems should also boost the accuracy of the more general radio and television broadcasts. But communicating this greater precision without snowing the public with details may be a problem. "If I know that it's going to start and stop raining seven or eight times in the next two days and that sometimes it'll be bright and sometimes dull, I'd have a hard time getting this across in the time the media would let me have," notes meteorologist and radio weather broadcaster Elliot Abrams, a senior vice-president of Accu-Weather (State College, Pa.), a private forecasting company.

One component of PROFS—the advanced doppler radar—is the centerpiece of another federally sponsored weather detection effort called Nexrad (next-generation weather radar). The purpose of Nexrad, which is funded jointly by the NWS, the FAA, and the Defense Department, is to spot severe storms far earlier than is possible with conventional radar (HIGH TECHNOLOGY, July/Aug. 1982, p. 82).

Like ordinary radars, doppler systems can gauge the distance to a storm by the time it takes transmitted microwaves to bounce off the precipitation particles and return. But the new systems will also measure winds, by exploiting the well-known doppler shift: Particles of water or debris that the wind carries away from a radar beam lower the frequency of the reflected signal, and objects carried toward the beam increase this frequency. (Winds perpendicular to the beam do not affect its frequency.) In practice, echo signals from a storm are displayed on a monitor in false colors that indicate the direction of the winds. In a Nexrad prototype under development by Sperry (Great Neck, N.Y.), for example, "cool" colors like blue and green indicate air movement toward the radar



NOAA/PROFS

PROFS computers give meteorologists a variety of innovative weather displays. Top to bottom: a storm's predicted course; cloud elevations and depths over time (bar color indicates severity of the storm); and wind speed as a function of both altitude and time.

while reds and oranges show movement away. The radars will be able to measure wind speed at a range of 145 miles.

Such measurement is crucial to detecting the most violent storms of all—tornadoes. While twisters sometimes show a characteristic hooklike pattern on conventional radar, they usually must be spotted visually. "The tornado is typically on the ground doing damage by the time forecasters can issue a warning," says Nexrad program director Anthony F. Durham.

Doppler radars can produce more timely warnings by identifying a pattern of air movement called a mesocyclone—a 6- to 12-mile-wide rising spiral of air that often spawns tornadoes. Using doppler radar, forecasters can also spot the tornado vortex itself, which appears as a region of rapidly changing wind speeds much smaller than the parent mesocyclone. That way they can issue a tornado warning even if the twister hasn't been sighted. Durham says tests have shown that Nexrad can extend warning times to 20 minutes, versus the zero to two minutes provided by conventional radars. Nexrad can also warn of violent hail and torrential rain. Toward the end of this year, NOAA will choose either Sperry or Raytheon (Wayland, Mass.) to build about 170 of the systems, which are to be deployed around the country by the early 1990s.

While ground-based storm-tracking systems such as Nexrad will help weather prediction tremendously, there is still no substitute for the global picture provided by satellites. Great strides have been made in space-based weather observation. Computers not only generate revealing false-color snapshots but can now assimilate data fast enough to create movielike pictures of atmospheric phenomena. These capabilities were demonstrated last September for millions of TV viewers who watched the National Hurricane Center follow Hurricane Gloria as it churned its way up the East Coast.

The tracking system used for Gloria is called McIDAS (man-computer interactive data access system), originally developed at the University of Wisconsin in the early 1970s. The system now consists of a massive data collection network that feeds visible and infrared images from satellites and ground-based weather stations into an IBM mainframe computer. Users of McIDAS—including NASA, the National Severe Storms Forecast Center in Kansas City, the National Hurricane Center in Miami, and many U.S. and overseas universities—can summon a variety of specialized computer-processed images on video terminals. These include multicolor composites of radar readouts, conventional and satellite weather data, and forecast information in two- and three-dimensional displays, as well as time-lapse movies of these analyses.

Right now, McIDAS is primarily a weather-tracking system. But "we're developing some sophisticated forecast models" that will enable McIDAS to predict the future movement of storms and other weather systems, says Thomas H. Achtor, a meteorologist at Wisconsin's Space Sciences and Engineering Center. To obtain the necessary computing muscle for these feats, says Achtor, McIDAS will soon link up with a powerful Cray machine at the World Weather building in Washington.

In the future, doppler radars will give pilots advance warning of wind shear conditions, which have been blamed for several recent plane crashes.

For most businesses and individuals, improved weather monitoring and forecasting is a matter of convenience or economics. For the aviation industry, it can be a matter of life and death. Both the National Weather Service and the FAA have embarked on projects to enhance air safety by completely automating weather observations at airports. At present, a human observer, who often has other things to do, takes weather readings once an hour. But "things can change radically in an hour," notes James C. Dziuk, manager of weather coordination at the FAA.

The FAA's program, known as AWOS (Airport Weather Observing System), calls for providing control towers and pilots with continuous measurements of temperature, dew point, wind speed and direction, precipitation, visibility, and cloud height. The National Weather Service has a similar effort called ASOS (Airport Surface Observing System), to be installed at the 250 medium-size to large airports at which NWS takes weather observations now; the FAA's system will serve about the same number of smaller airports. Plans call for installation of AWOS and ASOS to begin in 1988, with completion scheduled for around 1992.

While the instruments to be used in AWOS and ASOS include such old standbys as thermometers and barometers, some new gadgets may also make an appearance. One is a laser "ceilometer," a device for measuring the altitude of cloud bottoms. A laser will flash a pulse of light upward, and a photodetector will sense the reflected signal. The time lapse between emission and detection tells how high the cloud ceiling is.

Both the FAA and the NWS are now testing these compact instruments, in hopes that they can replace the cumbersome method now used. In that procedure, one observer shines a beam of ordinary light straight up to illuminate a spot on the cloud, and another observer some distance away focuses a second beam on the same spot; knowing the distance between the two observers and the angles involved permits triangulation to determine cloud height.

Another piece of hardware that may debut at airports is a visibility sensor to replace today's subjective reports by human observers. In one prototype under study, a light beam is shined at a photodetector one meter away and slightly off the beam's axis. The foggier or hazier the air, the more the light is scattered, and the greater the amount received by the detector. The strength of the received signal can then be translated into visibility in miles.

This visibility sensor may also be able to detect the intensity and type of precipitation, according to the FAA's Dziuk. The NWS's top candidate for sensing precipitation, however, is a laser instrument. The laser beam is focused on a detector about 30 meters away, and rain, snow, or hail falling through the beam disrupts it, forming a characteristic light pattern that the detector converts into an electronic signal. Computer analysis then reveals a "signature" identifying both the type and rate of precipitation. Like the other advanced instruments, this system is now getting tryouts at several airports across the country.

AWOS and ASOS systems will still be unable to pick up a dangerous phenomenon known as wind shear—a sudden change in wind speed or direction that imperils planes landing or taking off. Several recent aviation disasters, such as the crash of a Delta Lockheed L-1011 at Dallas/Fort Worth Airport last August with a loss of 133 lives, have been linked to wind shear.

One of the deadliest forms of wind

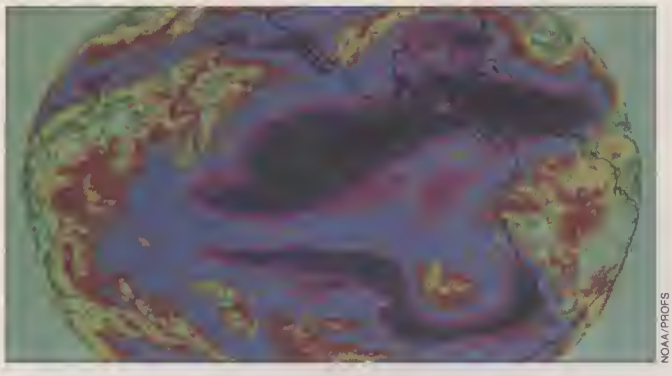
shear is known as a microburst—a violent downdraft that hits the ground and fans out in all directions. Upon encountering a microburst, a plane first feels an increase in airspeed as it flies into the outrushing air. A pilot unaware of the condition might then reduce engine power to maintain the proper flight path. But when the plane reaches the other side of the microburst, it is moving *with* the wind; air speed drops precipitously, and with engines now at low power the plane can easily stall and crash.

Because wind shear in general and microbursts in particular are usually localized and short-lived, they are not easy to spot. An interim method, in use at least until more sophisticated systems can be devised, is to encircle an airport with old-fashioned wind-measuring devices called anemometers. These are useful only near the ground, though, and a truly effective warning system must be able to measure winds as high as 1000 feet.

One way of doing this is with ground-based doppler radars like those to be used in the Nexrad system. Such sensors—being developed by NOAA's Severe Storms Laboratory in Norman, Okla., in conjunction with the FAA—detect radar returns from the heavy precipitation that often accompanies dangerous wind shear. The FAA has been testing a doppler radar at Memphis International Airport for more than a year and has installed a system at Denver's Stapleton International Airport. Results have been encouraging, says the FAA's Dziuk.

The wind shear monitors now being tested are used to alert the control tower, which then relays the warning to pilots. Even better would be an on-board detector to alert pilots directly. Systems already marketed by such companies as Sperry and General Motors' Delco Electronics Division (Kokomo, Ind.) are a step in the right direction; they sample airspeed at different parts of the plane, such as the nose and the tail, and flash warnings if there are any radical differences. The problem with these systems is that "they tell you you're already in a wind shear," says Jean Lee, a wind shear specialist at the Severe Storms Laboratory. "What you want is advance warning" in time to take evasive action.

The FAA has been studying several concepts for adding early warning capabilities to on-board detectors. One uses infrared sensors and is based on the assumption that wind shears ahead



NOAA/PROFS

Global variations in water vapor levels show up in false colors in a view pieced together from numerous satellite images by McIDAS.

Accu-Weather's Abrams foresees that the greater precision now becoming available could be hard for meteorologists to convey without confusing the public with details.

SSEC/UNIVERSITY OF WISCONSIN

of the aircraft create a slight temperature rise. But Dziuk says tests have shown that this is not always the case. The premise behind another technique is that sudden wind shifts affect the reflectivity of air to a laser beam in characteristic ways. But the range of laser systems is insufficient to provide the 20 seconds or more of warning that the FAA deems desirable.

Emphasis is therefore shifting to an airborne version of the doppler radar. Such a system presents some formidable obstacles, though. Microbursts usually occur during heavy precipitation, when the highly reflective raindrops ease detection by radar. Yet rain can evaporate on its way down, and these dangerous winds may occur at low altitudes where no drops reach. Thus in order to give a timely warning, the sensor must emit a beam strong enough that its echo can be distinguished from the dust, insects, and debris found in clear air thousands of feet ahead. Radars with the necessary power may be too large, and may consume too much power, for use on most aircraft, according to Lee.

Wind shear sensors, like most other weather-tracking systems, focus on conditions within a few thousand feet of the ground. But the need for more accurate measurements does not stop there. As a result, instrument makers are developing better ways of extending the weather picture into the upper atmosphere. For many years, balloon-borne instrument packages called radiosondes have beamed wind data (as well as temperature, pressure, and humidity readings) to ground receiving stations. But because they can drift for many miles after launching, balloons do not provide the accurate vertical profiles of the atmosphere that are so useful in assembling forecasts.

Unfortunately, the doppler radar used to monitor winds nearer the ground don't work at high altitudes, where there is little moisture or debris to reflect the beam. There are, however, turbulent eddies of warmer or cooler air that drift along at the speed of the prevailing wind. These eddies are invisible to standard weather radar but not to special low-frequency systems emitting wavelengths of several meters (the diameter of a typical eddy). As with other doppler radars, wind speed is inferred from the frequency shifts in the reflected signal.

Satellite-borne lasers can provide profiles of atmospheric wind, temperature, and humidity at different altitudes to improve forecasts.

One low-frequency radar system for detecting wind speed and direction aloft is now under development by a small electronics and instrument company called Radian (Austin, Tex.). Unlike the dish antennas used with most radars, the Radian system, trade-named Capsonde, uses an antenna array resembling a field of TV aerials. The antennas transmit radar beams vertically (to measure updrafts and downdrafts) and at two angles slightly off from the vertical (for east–west and north–south winds). After computer analysis of the time delays and frequency shifts in the echoes, Capsonde prints out the wind speed and direction for a series of altitudes programmed in advance by the system's operator.

Prototypes of Capsonde are now being tried by three organizations: NASA, to monitor upper-air activity that might affect the launch of the Space Shuttle; NOAA, to study the formation, path, and intensity of storm systems over the Great Plains; and the Army, as part of the Strategic Defense Initiative, to study atmospheric anomalies that might deflect a laser beam aimed at missiles. In addition, says Capsonde product manager Russell Peterman, airlines have shown interest in using the $200,000–$500,000 system to route planes most economically by taking best advantage of tailwinds.

While Radian is grooming its Capsonde units to monitor upper-air winds in one location, RCA is developing a laser system to measure winds globally from a satellite perch. In fact, RCA believes that its lidar (light detection and ranging) device could get a fix on temperatures and humidity as well.

Lidar, roughly analogous to radar in that it "sees" objects by bouncing radiation off them, has already served in a variety of remote sensing applications as well as some airborne meteorological experiments. Both NASA and the Air Force are "very interested" in RCA's proposal to place lidars aboard satellites for weather detection, according to Fred E. Shashoua, manager of advanced payloads at RCA AstroElectronics (East Windsor,

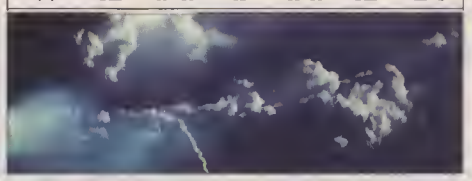
Better forecasts could end dry spell for government rainmaking

Rainmaking—or weather modification, as the government calls it—has hit hard times. The Department of Defense dropped its rainmaking effort in the mid-1970s, and in 1983 congressional budget cutters axed the program run by the National Oceanic and Atmospheric Administration (NOAA). The only remaining federally sponsored weather modification projects are at the Interior Department's Bureau of Reclamation, which is trying to increase winter snow packs in the West (to boost springtime runoffs) and to increase summertime precipitation in North Dakota.

A key reason that NOAA's once extensive program has withered is that "we were having difficulty proving success," concedes NOAA meteorologist Harold Corzine, who monitors all weather modification projects in the United States. Cloud seeding, usually with crystals of silver iodide or dry ice, is done only in clouds that are likely to produce precipitation anyway. It is therefore hard to demonstrate what percentage of the precipitation that actually falls is due to the seeding; since no two clouds are exactly alike, it is impossible to compare a seeded cloud with a nonseeded control.

Although the federal cloud seeding programs have shrunk, commercial rainmaking is still going strong, particularly in the West. Such companies as Atmospherics (Fresno, Cal.), Colorado International (Boulder), and North American Weather Consultants (Salt Lake City) have found a profitable niche in catering to agribusiness firms and ski slope operators, as well as states, counties, and municipalities.

At present, the outlook for a revival of weather modification programs at NOAA is bleak. "I don't think we'll get back to it until things loosen up quite a bit," says Corzine gloomily. But he feels that the key to loosening Congress's purse strings is to prove that weather modification is effective. The way to do this, he says, is to improve weather prediction in general. "Until you can predict things better, it's very difficult to say what would have happened" in the absence of cloud seeding.

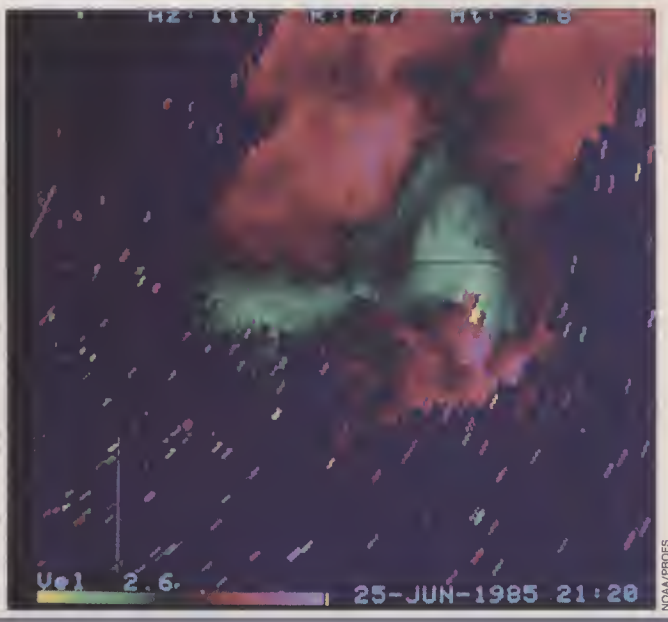


N.J.). Although no agreement has been reached, Shashoua hopes the units can be placed in space by the mid-1990s.

Lidar is needed to fill a critical gap in weather observation technology, according to Shashoua. On the one hand, he says, "balloons give you good measurements, but you can't cover the whole world with them." On the other hand, existing satellite instruments that monitor temperature and humidity by measuring the atmosphere's reflected infrared radiation tell nothing about how conditions vary at different altitudes. Lidar, says Shashoua, could make global readings with altitudes accurate to within 1 kilometer.

Lidar measurements of wind speed and direction take advantage of the frequency shifts of laser light as it bounces off minute particles in the air. As with doppler radar, particles moving toward the light source increase the beam's frequency while those moving away decrease it. Altitudes of the winds would be determined from the known height of the satellite and the light beam's round-trip transit time. Because the beam pierces the atmosphere at an angle, it is sensitive to crosswinds as well as to vertical air motion. Shashoua believes that airlines could save "hundreds of millions of dollars" in fuel per year by using the system to locate favorable tailwinds and avoid strong headwinds. Lidar could also aid forecasters in tracking the jet stream (strong upper-air winds that often steer weather systems).

To measure humidity, the satellite-borne instrument would emit two laser beams—one tuned to a frequency absorbed by water molecules, the other tuned slightly higher or lower. The difference in the brightness of the two reflected beams would indicate the amount of water vapor in the air. A similar dual-beam system would take the atmosphere's temperature. In this case, one beam would be tuned to a frequency absorbed by oxygen, the density of which depends on temperature.



NOAA/PROFS.

In addition to improving daily forecasts, these detailed profiles should give a more scientific basis to what is now virtually a black art: long-range weather prediction. Monthly and even seasonal forecasts are in demand among large agribusiness firms, utilities, and oil refiners, among others, as aids to planning. Unfortunately, long-range forecasts routinely issued by the NWS's National Meteorological Center give only vague probabilities of warmer, colder, or wetter than normal conditions.

For medium-range forecasts, out to about five days, meteorologists use mathematical models based on theories of atmospheric physics. They plug into their equations worldwide data on temperature, pressure, wind circulation, and other variables. The results, generated by supercomputers such as the Cyber 205, are a series of maps that show what weather patterns may look like over the next few days. Meteorologists then convert the maps into forecasts.

To look ahead a week or more, however, these models prove inadequate, because certain simplifying assumptions used in the calculations can no longer be made. For instance, it is common to ignore variables that are hard to predict, such as changes in ocean surface temperatures and the effects of complex

Doppler radar can warn of a tornado before it is visually spotted. Winds moving toward the radar show up as a different color from winds blowing away.

NOAA/PROFS.

Government gives a boost to weather instruments

Meteorological instruments—a business sector that encompasses devices ranging from thermometers to satellites—has traditionally been a slow-growth field. But several large government-sponsored high technology projects are expected to give it a shot in the arm over the next decade.

For example:

- In 1988 the Federal Aviation Administration (FAA) is planning to begin the installation of 110 doppler radar systems at various airports to detect wind shear; the cost of this project will be approximately $330 million.
- A highly sophisticated next-generation doppler radar system called Nexrad is under development by the National Weather Service (NWS) and other government agencies; intended for early warning of tornadoes and other dangerous storms, 160 of these units, costing $1–2 million each, will be deployed nationwide beginning in 1988.
- A new type of satellite that measures global weather conditions by means of lasers beamed down into the atmosphere is under consideration by the National Aeronautics and Space Administration and the Air Force; such a satellite would cost about $100 million.
- At least 100 ground-based systems using radar to profile weather conditions in the upper atmosphere are expected to be deployed by the NWS after 1992; although the exact number of systems to be used hasn't been determined, each will be priced at around half a million dollars.

Other federal programs will also boost the need for weather instruments. The National Oceanic and Atmospheric Administration (NOAA), for example, is planning a system of closely spaced, automated weather stations that will be used to improve local forecasts; the system will be implemented nationwide in the 1990s. In addition, the FAA and the NWS have programs aimed at automating collection of meteorological data at more than 400 airports throughout the country beginning in 1988.

As government programs get underway within the next two years, sales opportunities will open up for makers of meteorological instruments. The initial beneficiaries of government contract work will be large aerospace, electronics, and engineering firms such as Sperry (New York), Raytheon (Lexington, Mass.), and RCA (New York). Although weather instruments are only one part of these companies' business, such firms play leading roles in the industry. RCA has long been a manufacturer of weather satellites, for example, and Sperry and Raytheon—both of which are seeking the lucrative Nexrad contract—have extensive experience in weather radar.

"Sperry has hired expert meteorologists to work with our engineers and programmers in developing the kind of easy-to-use, next-generation weather radar systems being sponsored by the government."

Herbert Chodosh
Marketing Director
Surveillance & Fire Control Systems Division
Defense Products Group
Sperry

"Government programs will open up new opportunities for the production of automated weather stations. It will not take much retooling for us to address that market."

Carl Weiss
Assistant Sales Manager
Belfort Instrument

Small, specialized meteorological-instrument houses will also benefit from government projects, particularly those calling for a denser network of weather stations or for automating observations now made manually. In particular, "there is likely to be strong interest in equipment that links sensors to computers, either remotely or through built-in microprocessors," says Daniel A. Mazzarella, president of Science Associates (Princeton, N.J.), a meteorological-instrument consulting firm.

NOAA's program, for example, will use a central computer to process wind speed, pressure, and other data collected from sensors and other instruments. The FAA and NWS projects to automate meteorological measurements at airports will also involve continuous relay of precipitation, visibility, and other data to computers for analysis and display in control towers.

Several firms that produce weather-instrument packages (as opposed to individual sensors) are in a position to take advantage of these program requirements. These packages combine sensors that monitor such weather variables as temperature, humidity, and atmospheric pressure with communications devices and computerized data processing and display equipment; they usually cost from $50,000 to several hundred thousand dollars.

Among these firms, some produce packages dedicated to single tasks, such as the lightning detection systems from Lightning Location and Protection (Tucson, Ariz.) and the atmospheric profiling equipment sold by Radian (Austin, Tex.). Other companies offer general-purpose equipment. Belfort Instrument (Baltimore) is a major supplier of ground-based, self-contained meteorological stations that are widely deployed by the National Weather Service; in 1982 Belfort purchased most of the instrument product lines of Bendix (which later merged with Allied).

Other market leaders that may be competing for a role in government programs include Met-One (Medford, Ore.), Climatronics (Hauppauge, N.Y.), and Qualimetrics (Sacramento, Cal.), which acquired Science Associates last year.

—Gordon Graff

temperature and moisture feedback mechanisms between the atmosphere, land, and sea. "These simplifications are invalid for longer time ranges, particularly over a whole season," says Donald Gilman, chief of predictions at the NWS's Climate Analysis Center (Camp Springs, Md.). "But the unsimplified problem remains beyond the state of the art in computing."

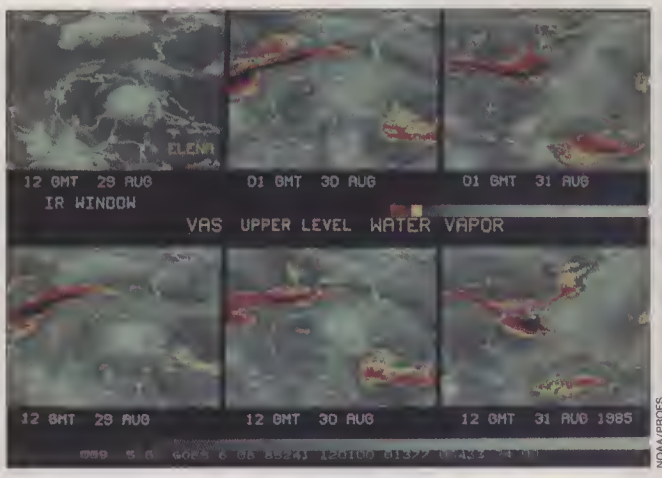
For monthly and seasonal forecasts, therefore, statistical and climatological considerations are preferred to atmospheric models. Prediction then becomes a matter of estimating the extent to which temperatures and precipitation are likely to deviate from the norms during the forecast period. This is done by comparing maps of "normal" atmospheric circulation patterns with those derived from recent measurements. Anomalies in these patterns are noted, and extrapolations are made from past experience to predict how long they will persist, whether they'll move, and, if so, how far.

Making predictions on the basis of these anomalies, however, "is a very empirical thing, and we have to be very cautious about it," says Gilman. The results bear out his hesitancy, with monthly temperature predictions that are only about 30% closer to the mark than what could be obtained using climatological data found in common almanacs. Over the next 10 years, says Gilman, this margin should improve to 40–45% as atmospheric models now used to make forecasts out to about 10 days are improved to cover a whole month. "To do this will require really big computers and several years of running test cases," he says. Such long-term modeling work is under way at the National Meteorological Center and the European Center for Medium Range Weather Forecasting (Reading, England).

But better climatic models aren't the only solution to the problem of long-range forecasting. An effort called TOGA (Tropical Oceans and Global Atmosphere) is aimed at fleshing out the currently scant data on conditions over the tropical oceans, which act as giant heat engines to drive much of the world's weather. Sponsored by NOAA, NASA, and the U.S. Navy, TOGA will use advanced instrumentation mounted on satellites that will be launched around 1989 in collaboration with several Western European governments.

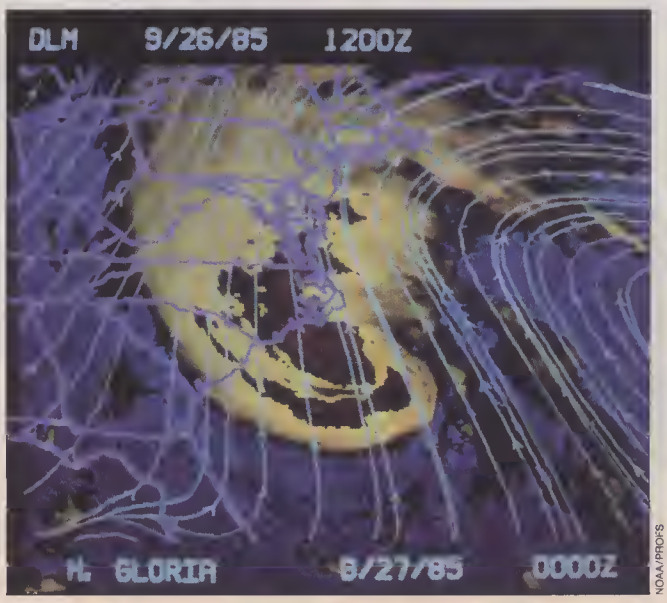
Among the instruments to be deployed will be devices that measure the ocean's temperature by its infrared emission, and scatterometers to gauge surface winds from the way light reflects off ocean waves. Also included will be altimeters that measure ocean heights to a precision of a few inches by bouncing radar waves off the sea surface and analyzing their return times. Such readings could help monitor the position of ocean currents (such as the Gulf Stream), which stand a few inches higher than surrounding water.

One goal of TOGA, says Robert W. Reeves, a meteorologist with the program, will be to study El Niño, a warming of the Pacific Ocean off the South American coast that recurs every three to seven years. The disruption of atmospheric circulation that results from El Niño has been linked to droughts, floods, and unusually high or low temperatures in many parts of the world. The task, explains Reeves, will be to "capture" an El Niño—detect every phase from onset to decay—by recording its temperature, position, and duration. Then its characteristics will be correlated with climatic variations in the United States. Ultimately, says Reeves, "we'd like to develop some predictive scheme for each of these episodes." Perhaps, he adds, this will allow advance warning of disruptive weather caused by the episodes.



Computers blend visible and infrared satellite images to track a hurricane.

Long-range forecasting will always be chancy, however, and most meteorologists expect more progress in short-range predictions. "I see the greatest improvements coming in the zero- to twelve-hour period and the one- to two-week forecasts," says NOAA's MacDonald. By the turn of the century, he says, forecasters may be able to say that one week from today there will be a 10% chance of rain in the morning and a 40% chance in the afternoon. And two-week forecasts may have the kind of specificity we now associate with two-day forecasts—that is, a better-than-chance guess at the overall weather. Nevertheless, MacDonald cautions against expecting too much. "We are making progress," he observes, "but weather will never be as predictable as the motion of the planets."□



Watching Hurricane Gloria's attack: A computer superimposes pressure contour lines on a satellite picture to aid tracking.

Gordon Graff, a New York–based writer, is a former senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*


PAIR?
PARE?
PEAR?

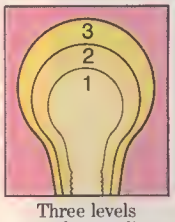
Would you like to know how computers can tell the difference between a pair in a poker game and a pear on a plate?

How they can understand a variety of speakers with a diverse variety of accents—and reply in pear-shaped tones, using normally connected speech?

Then read on to learn more about computers that recognize words, comprehend meaning from context, even synthesize human speech from a mere shadow of itself.

It's All In The Algorithms

Utilizing three levels of speech-processing algorithms, AT&T is giving the computer a more 'robust' understanding—the capacity to comprehend connected speech from different speakers.



Three levels to understanding

Acoustic pattern matching (1) identifies the spoken words.

Grammatical processing (2) figures out how the words are put together.

And semantic processing (3) extracts meaning from the context. With each successive step, the computer moves closer to accurate understanding.

Acoustic pattern matching determines how much latitude the waveform (pronunciation) of a word can have before it becomes unintelligible to the computer.

By isolating the specific characteristics the waveform of a word contains—independent of the accent of a speaker—we increase the probability that it will be correctly matched to a pattern stored in a computer's memory. But, correct recognition of words is only the beginning of computer understanding.

Computer Grammar 101

Grammatical processing further increases the probability of recognizing words. It analyzes them within the constraints imposed by language—the allowable sequences of syllables in a word or words in a sentence.

For a specific vocabulary and situation, it is possible to define every sequence the computer can recognize. Based on probabilities assigned to each word it recognizes—and where that word falls—the computer determines which of its possible sequences is the most likely. This process gains two advantages: It allows words that might not otherwise be recognized to be correctly accepted; and it speeds up processing time by using sequence position to limit the number of words it looks at for a pattern match.

A Meaningful Relationship

Semantic processing is the point where the computer crosses the line between recognition and understanding—the point where words are given meaning within a specific context. This endows a system with one of its most human qualities: knowing when a request isn't understood, and asking for appropriate clarification.

Talk Isn't Cheap

Making a computer listen intelligently is one thing; making it respond intelligibly, however, is another.

Enabling a computer to talk, reproducing the subtleties of human speech, has required large amounts of memory—a high cost item. Therefore, an 85 percent reduction in the amount of information needed to store and generate high-quality speech can mean significant cost reductions.

That's just what a new AT&T speech synthesis technique, called multi-pulse linear predictive coding (MP-LPC), provides. It reduces the 64 thousand bits per second previously needed to 96 hundred.

Speech signals mimic the human vocal tract—they have redundancies built in. MP-LPC codes speech to remove these redundancies, then tells the computer how to reconstitute the original speech from the mini-version in its memory. This coding eliminates unnecessary bits from being stored and transmitted.

Getting Down To Business

At AT&T, our goal is to make computers listen and understand as fast as people speak—and speak to and understand as many people as possible. Speech-processing algorithms, developed by AT&T Bell Laboratories, have moved us several steps closer to that ideal.

For example, most speech recognition systems make the speaker pause between words. But AT&T, using advanced recognition algorithms, has developed a Stock Quotation System that allows callers to enter and retrieve current market information in natural, normally-connected speech. Users simply speak the number codes for any of over 6,000 stocks, and the service provides current quotes—delivered in computer-generated speech. The system is now in initial service for customers of a major brokerage company.

Numbers are nice, but make for limited conversation. Closer to our goal of a conversational computer is the Flight Information System. It uses the Official Airline Guide as its data base. In its limited environment, this laboratory system converses with the user in natural speech in response to normal flight information queries.

One Of Our First Callings

AT&T has been deeply involved in speech technology since the genesis of the telephone. From the beginning, our goal was to make mechanical communications fast, foolproof and economical.

Today, with the advent of the computer, we're moving toward the ultimate ideal: creating machines that serve our needs and save our energy in the most natural manner—by voice command.

AT&T
The right choice.

PROGRAMMING WITHOUT TEARS

Developments in computer software have given a productivity boost to nearly every profession. Clerical workers have word processing and electronic mail, managers have decision support systems and spreadsheets, engineers have computer-aided design tools. Ironically, the one calling that has managed to escape the trend to automation is computer programming. For the most part, software is still developed much the way it was 20 years ago. But that situation is changing, thanks to more productive programming languages and to software that helps write software. With these new tools, even nonprogrammers can create simple applications for their own use.

Until now, dependence on traditional programming techniques has slowed companies' efforts to use information technology. Well over 100,000 database management systems (DBMSs) of all types are in use worldwide—up from fewer than 300 in 1970, according to George Schussel, president of Digital Consulting Associates (Andover, Mass.). But data processing departments are typically bogged down with three years worth of requests to produce application programs that would make the data more meaningful and accessible to managers. Meanwhile, approximately 60% of the total yearly business expenditures on computers goes to fixing and updating aging programs written in COBOL—the most common business programming language—rather than to producing new ones, says Vaughan Merlyn, whose Atlanta-based firm Merlyn Consulting specializes in application development productivity.

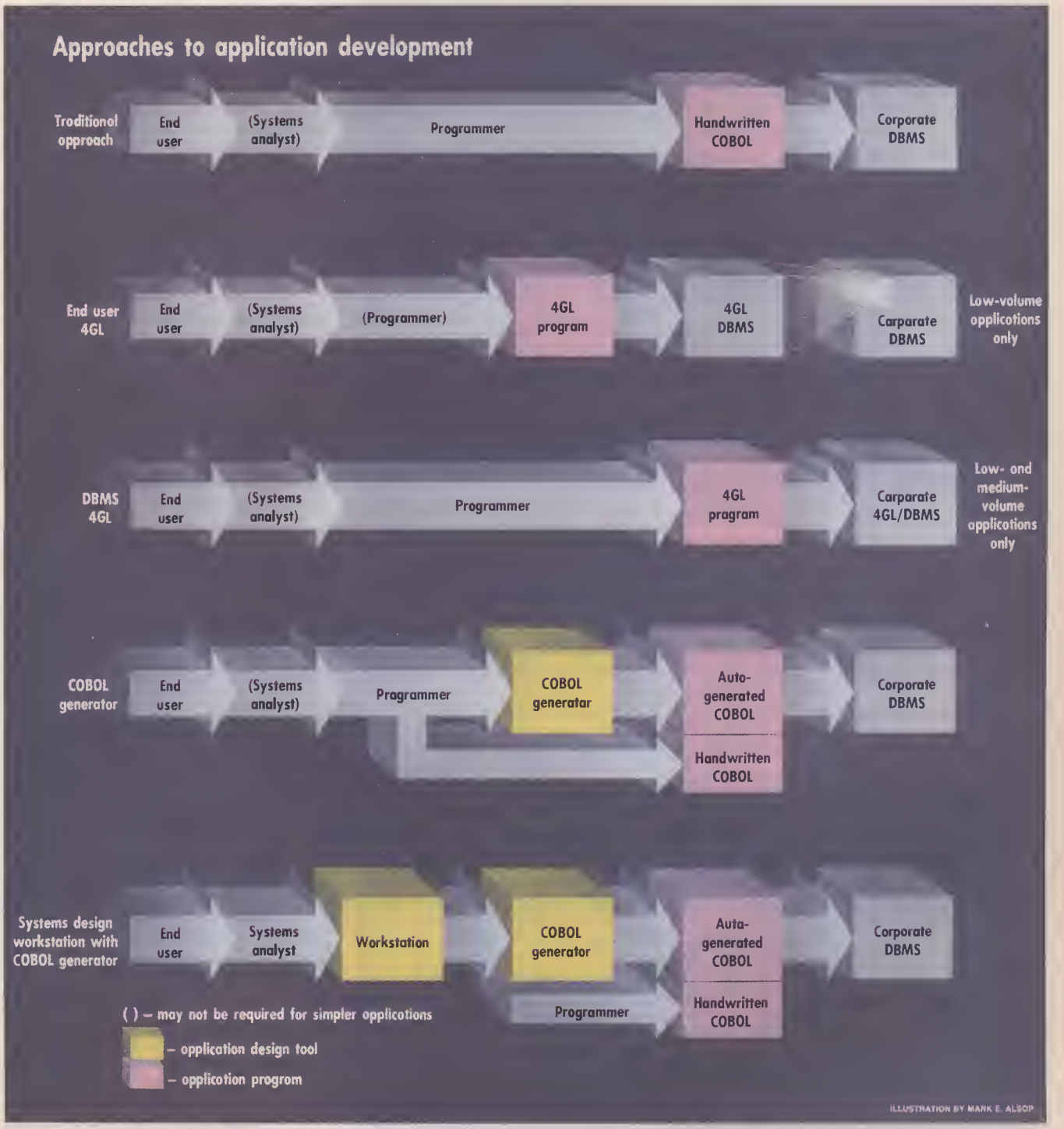
Many corporations are mounting a three-pronged attack on this information bottleneck. They are acquiring fourth-generation programming languages that permit programmers to churn out applications in record time—and that even let computer-illiterate users write simple programs. They are bringing in COBOL generators that automatically produce COBOL code under the direction of programmers. And they are equipping information systems staff with intelligent, graphics-oriented workstations that could do for application program designers what computer-aided design workstations have done for engineers.

New languages and tools are making software developers more productive and enabling novices to write programs

Software generations. The years between 1955 and 1965 were good ones for programmer productivity. Over that decade, the form in which computer instructions were written advanced two generations beyond first-generation machine language, which consists of rows of binary *0*s and *1*s that the machine can use directly. Assembly language, the second generation, essentially established English mnemonics for each machine language instruction, making the programming process much less onerous. Third-generation languages such as FORTRAN, COBOL, and PL/1 broke away from the one-to-one relationship between machine and assembly languages: A single statement in COBOL, for example, might generate several hundred machine-language instructions. These increases in the power of computer language statements resulted in a 50-fold reduction in the time it took to write a typical program, Schussel estimates. Since then, however, progress has been slow.

Fourth-generation programming languages (4GLs) first appeared in 1973, but only recently has the market begun to assimilate and exploit them. These languages are closer to English than their predecessors, making them relatively easy to learn. If using the Nomad2 4GL, for example, a programmer who wanted to double the salary of all programmers in the company would write: "change all employee salary to employee salary x2 where skill contains programming." A COBOL program for the same purpose would require dozens of lines of code, all of it unintelligible to a nonprogrammer. Another salient feature of 4GLs is their nonprocedural format: Users need specify only what it is

by David H. Freedman



Users who need to obtain information from a corporate database traditionally work through systems designers (who define the overall application) and programmers (who write the necessary software). Fourth-generation languages (4GLs) can let users write their own programs and can increase the productivity of professional programmers as well. An end-user-oriented 4GL first interacts with its own internal database, which in turn accesses data from the full database. DBMS-oriented 4GLs generally work only with database management systems sold separately by the same vendor; they also give programmers more tools with which to build larger applications than the end-user 4GLs. The popular third-generation language COBOL is more flexible than the fourth-generation languages but also more difficult to learn and use. However, COBOL generators can automatically produce up to 80% of a program's code, leaving only 20% for a programmer to write manually. Systems-design workstations help analysts develop an application's overall design, and can be linked by software bridges directly into COBOL generators, which then produce programs based on the analyst's specifications.

they want the program to do, as in the above example, and not how to do it. With COBOL, a decidedly procedural language, typically 80% of a program consists of commands that tell the computer which instruction to process next.

But beyond these basics, the term "fourth-generation language" has come to embrace such a wide variety of products that many experts recommend ignoring it altogether. "Fourth-generation languages are essentially a philosophy," maintains consultant Merlyn. A more concrete picture is given by an oft-quoted definition from James Martin, an independent consultant and a guru of information systems management: "A 4GL is a language whose basics can be learned in two days and that offers at least a ten-to-one productivity gain over COBOL." In any case, these are some of the products that have been lumped under the 4GL umbrella:

• *End-user-oriented languages.* These are the classic 4GLs, designed for use by computer novices and pros alike. They generally run on large mainframe computers and combine the features of a database management system and a programming language. They are also usually compatible with popular DBMSs such as Cullinet Software's IDMS, and, increasingly, with easier-to-use relational DBMSs like IBM's SQL. Because they don't use computer resources as efficiently as the third generation, these languages are best suited for developing simple analytical programs that don't repeatedly run large volumes of data. Three products have this category more or less to themselves: Focus from Information Builders (New York), Ramis II from Martin Marietta Data Systems (Princeton, N.J.), and Nomad2 from D&B Computing Services (Wilton, Conn.). Prices range from $100,000 to $135,000.

With 4GLs, users specify what they want the program to do, not how to do it

• *DBMS-oriented languages.* These products are designed to work with a specific DBMS offered separately by the same vendor. Though not always as easy to use as the Focus-type 4GLs, these languages provide larger and more detailed sets of commands and can be used to develop more complex, higher-volume applications. Best-sellers in this category (listed with their associated DBMSs) include Ideal (Datacom/DB) from Applied Data Research in Princeton, N.J.; Natural (Adabas) from Software AG in Reston, Va.; and Inquire (Inquire) from Infodata Systems in Falls Church, Va. They typically cost from $50,000 to $80,000.

• *4GL-like tools.* A number of products can accomplish, within limits, what some of the above products do, even though they aren't really languages. Application generators like Gener/OL from Pansophic Systems (Oakbrook, Ill.) ease program development via menu options, simple commands, and "screen painting," with which the user creates an electronic mock-up of a paper document such as an insurance form. Another example is decision support development systems, such as one from Pilot Executive Software (Boston); these are application generators with integrated DBMSs geared to developing applications that provide summaries of corporate and competitive data along with "what if?" comparisons. And at the limit, some observers insist that Lotus 1-2-3 and other integrated spreadsheet products are also 4GLs.

However 4GLs are defined, one indisputable benefit is that they let programmers program faster—although how much faster is a hotly debated question. Vendors have been known to promise 100-fold increases in productivity, which may be true in some applications, but companies whose programmers achieve a seven-to-one improvement generally consider themselves ahead of the game. Richard Cobb, VP of Martin Marietta Data Systems' Information Technology Division, calculates that a five-to-one productivity gain enables a programmer to generate enough extra applications to save a typical company nearly $1 million over a three-year period. Bank of America is a believer, having realized productivity improvements of about ten to one when it started using Nomad2 10 years ago. Today 10,000 of the bank's employees—a third of them professional programmers—work primarily with that 4GL.

Fourth-generation languages could have an even greater impact on end users than on programmers. A novice

SHOW ME THE TOTAL, AVERAGE, MAXIMUM AND MINIMUM UNITS SOLD TO EACH CUSTOMER.

WHAT ARE THE TOTAL, AVE, MAX AND MIN UNITS THAT HAVE BEEN PURCHASED BY EVERY CUSTOMER.

I NEED TO KNOW THE TOTAL, AVE, MAX AND MIN UNITS PURCHASED BY EACH CUSTOMER. PLEASE GIVE ME THE ANSWERS I NEED.

GIVE ME THE TOTAL UNITS SOLD TO EACH CUSTOMER. WHAT WERE THE AVERAGE UNITS ALSO? INCLUDE THE MAX AND MIN UNITS AS WELL.

TABLE FILE SALES SUM UNITS AND AVE UNITS AND MAX UNITS AND MIN UNITS BY CUSTOMER END

CUSTOMER	UNITS	AVE UNITS	MAX UNITS	MIN UNITS
COMP. DEVELOPMENT, LTD.	57911	742	2300	127
ENGINEERING ASSOC.	11753	133	464	24
MOD MODELLING, LTD.	5373	89	282	19
ROYAL MFG CO.	55040	519	2075	117
SOFT PROCESSING INC.	19122	285	1500	45

RANK TOTAL COPIER SALES BY MARKET

PRINT THE RANKED TOTAL 1984 ACT YTD $ IN EACH MARKET OF ALL SALES DATA WITH PRODUCT LINE = COPIER & PRODUCT = TOTAL & MARKET NOT TOTAL & CHANNEL = TOTAL

MARKET	1984 ACTUAL YTD SALES
CHICAGO	$33,340,528
LOS ANGELES	$30,211,200
WASHINGTON	$20,295,200
NEW YORK	$18,848,800
LONDON	$16,684,200
BONN	$13,754,000

END OF PAGE—HIT THE ENTER KEY TO CONTINUE.

The Intellect natural language system accepts English queries typed into the computer, translates them into a language the DBMS understands, and calculates and presents the results.

With natural language processing systems such as RAMIS II English, users can ask a question in a variety of ways and still get the same results.

can use the basic features of a 4GL with just two hours of training, says Nicholas Rawlings, director and senior technical adviser at D&B Computing Services. At 3M, 12,000 nonprogrammers use the System 1032 4GL from Software House (Cambridge, Mass.) to glean information from the company's database. "That's 12,000 users that don't have to go to the information systems department for answers," says Software House's technical marketing manager Paul Perkovic.

Programmer resistance. COBOL fans needn't brace themselves for a 4GL takeover, however. Over 50 billion lines of COBOL are still knocking around inside corporate computers, and companies aren't about to rewrite them. But even when it comes to new applications, 4GLs meet stiff resistance from many programmers, who claim that they are blunt instruments incapable of producing finely tuned programs. Each successive language generation does in fact lose some of the flexibility of its predecessors. Because 4GLs generally lack such programming staples as loops, arrays, and string manipulations—a single statement in the newer languages is designed to encompass many functions of the former—they offer less control over the results.

```
0010 FIND PERSONNEL WITH STATE = 'NY' AND CITY    'ITHACA' OR    'NEW YORK'
0020 SORTED BY CITY NAME
0030 ACCEPT IF SEX = 'F'
0040 DISPLAY NAME FIRST-NAME CITY SALARY
0050 AT BREAK OF CITY DO SKIP 1 WRITE
0060    'TOTAL SALARIES:' OLD(CITY) T*SALARY SUM(SALARY)
0070    SKIP 1 DOEND
0080 AT END OF DATA DD SKIP 1 WRITE
0081    'AVERAGE SALARY:' AVER(SALARY) / 'MINIMUM SALARY:' MIN(SALARY) /
0100    'MAXIMUM SALARY:' MAX(SALARY) DOEND END

PAGE 1                                                    86-09-16 17:18:12
LAST-NAME      FIRST-NAME     HOME-CITY      FIXED SALARY
BONNER         ANN            ITHACA              10800
JENSON         PEARL          ITHACA               3010
SNYDERMAN      VENUS          ITHACA               3200

TOTAL SALARIES: ITHACA                             17010

BOOK           JENNY          NEW YORK            13800
FRONTERA       ANNETTE        NEW YORK            10200
HEAFNER        ELEANORE       NEW YORK            13800
MARTHALER      DIANA          NEW YORK            36000
RUBIN          SYLVIA         NEW YORK             3200
WALLACE        MARY           NEW YORK             5100

TOTAL SALARIES: NEW YORK                           82100

AVERAGE SALARY: 11012
MINIMUM SALARY:  3010
MAXIMUM SALARY: 36000
```

A moderately detailed program written in the Natural 4GL shows how different data and formats can be requested. Even nonprogrammers can understand the English-like program statements.

```
> LIST BY DEPT SUM (SALARY) AVG (SALARY) MIN (SALARY) MAX (SALARY)

PAGE 1
                SUM              AVG              MINIMUM          MAXIMUM
                CURRENT          CURRENT          CURRENT          CURRENT
DEPARTMENT      SALARY           SALARY           SALARY           SALARY
ACCOUNTING      56,000           28,000           22,100           33,900
FINANCE         52,900           26,450           24,300           28,600
MARKETING       84,300           28,100           24,500           32,800
SALES           68,000           22,667           19,200           28,800
```

Even without specific formatting requests, most 4GLs will arrange data in a logical, tabular format, as shown by this simple Namad2 database query.

"If a fourth-generation language is like one of those nifty new automatic cameras, then COBOL is like a manual SLR [single-lens reflex camera]," asserts DCA president Schussel, who lectures extensively on 4GLs. "If you know how to operate the SLR, you can make it stand up and dance." But some suggest that programmers also belittle fourth-generation languages because they're concerned about maintaining the market for their hard-earned COBOL experience. "A 4GL can be 'deskilling,' robbing programmers of career and pay opportunities," says consultant Merlyn, noting that a top COBOL programmer can make $15,000 more per year than a Focus programmer.

Even programmers who embrace 4GLs have to be careful to accept the languages' limitations. While 4GLs work well when it comes to noncritical, internal applications that don't demand a lot of computer resources, they are too inefficient for most powerhouse applications like order processing or payroll. New Jersey motorists learned that lesson the hard way last September when the Department of Motor Vehicles' Ideal-based vehicle registration system brought the department's computer to its knees, leaving a million drivers without registration. (Ideal vendor Applied Data Research claims it warned the system's developers that the language might be unsuitable for the high-volume segments of the application.) To avoid such problems, some data processing departments use 4GLs only to develop quick application prototypes; if the prototype works, they rewrite the program in COBOL.

End users can run into difficulties too. Although they can learn to write working 4GL programs, getting current and accurate data sometimes requires additional knowledge about how the corporate database is set up. Some companies maintain information in more than one database, and the 4GL language may not be compatible with all of them. Also, the English-like aspects of a 4GL may mislead novice users into thinking that it will "understand" their needs, even if these aren't specified in detail. For example, a user who simply requests a report on yearly sales might get fiscal year figures when calendar year figures were desired. Or invoices for goods shipped might be confused with invoices for goods received. Another problem that novice 4GL users can

face is that some information systems departments provide access only to copies of the actual database. If the copies aren't updated every time the main database changes, the user may end up with old or ambiguous data.

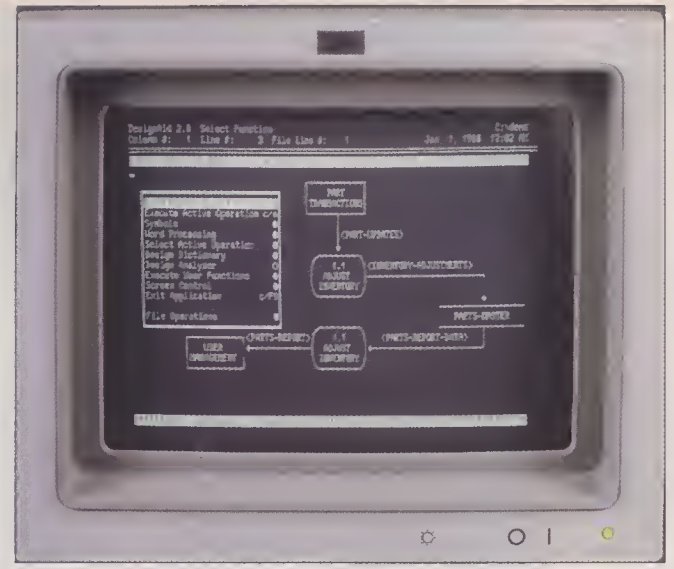
Despite the problems, Schussel says 4GLs and 4GL-like tools can now be found at about half the 17,000 mainframe sites in the U.S., and he expects penetration to hit 80% by 1990. By then, he adds, a large percentage of companies will have more than one 4GL.

The growth of 4GLs beyond 1990 may be tied in part to the spread of effective "natural language processing," which allows users to query databases in ordinary English. Although 4GLs are English-like, the user must still adhere to each language's vocabulary and syntax constraints. Natural language systems, on the other hand, employ rules of grammar and lexicons of commonly used words to translate English requests into a 4GL or some other database query language. With a good natural language system, a user can ask in a variety of ways for the same data, and the system will "understand" the common goal of each request.

The leader in this field is Artificial Intelligence Corp. (Waltham, Mass.), whose Intellect software lets a user type in requests such as "Give me a pie chart showing the population for each state in the Midwest." The program interfaces with several software products and languages, including Focus, and is installed at about 350 sites. Martin Marietta offers English and French natural language modules for its Ramis II; the English version contains a dictionary of 5000 root words and phrases, and, like Intellect, allows the user to build application- and user-specific dictionaries.

One problem with natural language tools is that because of the fuzzy syntax and semantics of real language, they are liable to misunderstand a command. Unless the system can detect ambiguous statements and request clarification from the user, it may provide apparently correct, but inaccurate, data. "I advise people to use these languages to experiment, not to build strategic systems," warns DCA's Schussel.

Some companies are employing natural language interfaces for applications broader than simply querying databases. One example is an application development system from Exsys (New York), which holds an English question-and-answer session to gain information about the user's needs. The system takes this information and automatically builds an application that works with the system's proprietary DBMS.



Systems-design workstations such as Nastec's CASE 2000 DesignAid ensure consistency in program development.

Other features likely to become common on 4GLs include layered interfaces that vary in complexity according to the sophistication of the user, like those of Software House's System 1032; integrated office automation functions such as document processing and electronic mail, like those offered with Natural; and completely menu-driven interface options, like the one available with Ramis II. Also, PC links into mainframe-based 4GLs have become de rigueur.

Design workstations like Knowledgeware's often include "action diagrams," which use brackets to show processes and subprocesses.

Information Builders has gone further than most in this regard with its PC/Focus, which lets users actually develop mainframe Focus applications on their PCs.

COBOL generators. Those who like the rapid application development powers of 4GLs but insist on running COBOL can turn to COBOL generators. These mainframe-based software packages draw on their libraries to produce chunks of high-quality prefabricated COBOL code—as much as 80% of a typical program. Tying the chunks together and customizing the program—the other 20%—is left to a programmer.

COBOL generators can spew out as much as 2000 lines of code a day, versus the 20 lines expected from the flesh-and-blood model, according to vendor Netron (Downsview, Ontario). Because of the time required to stitch together and customize the canned code, the productivity increase is not actually 100 to one, but it's comparable to that provided by a 4GL. And since the final program is in the efficient COBOL language, companies don't have to restrict the use of generators to low-volume applications, as they might with a 4GL. That's why some say COBOL generators are the best of both worlds.

Others say they are more like the worst of both worlds. After all, COBOL generators don't let programmers get at the language's high-precision tools; the resulting code, meanwhile, could require the kind of expensive maintenance that data processing departments are trying to get away from. Indeed, modifying automatically generated COBOL presents some unique problems. For one thing, much of the code the programmer will have to modify won't be something he or she actually wrote. For another, every time a change is required, the programmer must decide whether to make the change by hand or to regenerate the entire application. In the latter case, all previous hand-made modifications will be lost, since the generator has no way of incorporating them.

COBOL generators are newer than 4GLs and not yet as popular. One of the most widely used generators, Pacbase from CGI Systems (Pearl River, N.Y.), has an installed base of about 400, a fifth that

of the more popular 4GLs. Also, the $100,000 to $200,000 price tags of most COBOL generators don't encourage experimentation. But vendors are adding impressive features that could eventually put COBOL generators on top. Netron, for example, offers a "frame-based" structure that it claims isolates automatically generated code from handwritten and modified code; that way, users can regenerate an application without losing previous customization efforts. Pacbase incorporates project management capabilities in its system, and Higher Order Software (Cambridge, Mass.) has endowed its "Use.it" generator with a graphics-oriented interface similar to that of the easy-to-use Apple Macintosh personal computer.

Systems design. COBOL generators and 4GLs offer reasonable responses to the challenge of programmer productivity. But programming typically represents only 15% of the cost of the "application life cycle," as it is called by systems analysts, who are to programmers what engineers are to drafters. The life cycle consists of first determining the end users' requirements and then designing the application (ensuring, in part, that it works smoothly with any existing applications), writing the program, testing it, and maintaining it as bugs appear and users' requirements change.

There is a growing awareness among information systems managers that their departments may be tripping up in the critical design stage. "A fourth-generation language that offers a ten-to-one improvement in programming productivity doesn't do you much good if you're using it to build the wrong application," notes Merlyn. "All it means is that you'll be able to rebuild it ten times before you have a net loss in productivity."

If programmers have been trailing a bit in the productivity-through-automation revolution, then systems analysts—whose primary tools have consisted of pencil and paper—have been left in the dust. But now a new class of product is aiming to rectify this situation. Systems-design workstations bring to systems analysts the same type of capabilities that computer-aided design workstations have long offered engineers. And according to consultant Martin, such capabilities are sorely needed: "The design of the interlocking computer applications of a modern enterprise are no less complex than the design of a microchip or a jet aircraft."

The workstations, usually based on powerful PCs, provide sophisticated graphics-based design tools that help analysts create flow charts. Multiple screen windows, icon-based menus, and pointing devices speed editing and let users zoom in from a systemwide view to a detailed look at any element. Design-rule databases ensure that users don't violate design conventions: A user who assigned two types of permissible data for an order entry system at the systemwide level and then tried to permit three types at a detailed, "zoomed-in" level would be reprimanded by the system. "Encyclopedias" keep track of all objects, labels, and relationships, preventing inconsistent definitions and tracking the effects of changes throughout the system. Other modules offer project management features and complete application design documentation.

CHIP JAMISON

COBOL generators and 4GLs can greatly speed software development, but they have yet to reach their full potentiol, soys consultont Merlyn. "The ultimate programmer productivity tool," he notes, "is one thot lets you do without progrommers."

Perhaps most significant, many of these products can be networked. As a result, teams of developers can work independently on different parts of the same application, with a shared encyclopedia watching for conflicting entries among the users. This capability may ultimately be more important than how much the system helps individuals, says John Henderson, a professor of management science at MIT's Sloan School of Management. "The quality of the final product may have more to do with how the team works together."

Three similar workstation products

Fourth-generation languages defy software slump

In recent years, fourth-generation programming languages (4GLs) have emerged as one of the most powerful tools for developing application software more quickly and efficiently. Such programs help individuals access and manipulate accounting, personnel, sales, and other information contained in mainframe corporate databases.

Focus Research (West Hartford, Conn.), which tracks this market, covers five such products. Three of them—Focus from Information Builders (New York), Ramis II from Martin Marietta Data Systems (Princeton, N.J.), and Nomad2 from D&B Computing Services (Wilton, Conn.)—are languages that have been specifically designed to allow users who are not professional programmers to write simple application programs after only a few hours of training. The two other languages in Focus Research's market surveys—Inquire from Infodata Systems (Falls Church, Va.) and Ideal from Applied Data Research (Princeton, N.J.)—are aimed at more sophisticated users dealing with high-volume data applications. Other prominent 4GLs include ADS/OnLine from Cullinet Software (Westwood, Mass.), Natural from Software AG (Reston, Va.), and Mantis from Cincom Systems (Cincinnati).

The market for 4GLs was $120 million in 1985, according to Focus Research, which estimates that 20% of the 17,000 IBM mainframe sites in the U.S. currently use at least one such language. This proportion is expected to increase to 25% by the end of 1986, even with a 7% annual growth rate in the number of mainframe sites, which will add up to an installed base that is worth over $500 million.

Not surprisingly, the leading products are Focus, Ramis II, and Nomad2. Focus accounts for half of all new sales, and the other two products for an additional 34%. While all 4GL products target professional programmers, these three packages gain a significant edge by aiming at the nonprogrammer market as well: There are 50 million office workers, versus a mere half million programmers.

The outlook for 4GLs constitutes one of the few bright spots at present in the software industry. "While almost every facet of the software market has been squeezed in the past 18 months, fourth-generation languages have shown consistent growth," says John Worthen, president of Focus Research. For example, the firm's 1985 surveys indicate an increase of almost 20% in the number of sites that will acquire such a language in 1986, compared with no increase in the number expected to add new general-purpose data management software. Worthen explains that a corporation usually needs only one database system per site, while individual departments at that site may each require a 4GL to address different applications.

"It takes less time and skill to use fourth-generation languages than COBOL, but more computation is required. As computing power increases, therefore, users will increasingly turn to the newer languages."

John Worthen
President
Focus Research

"The essence of a nonprocedural language is that the user tells the computer what he wants it to do, and the computer figures out how to do it."

Gerald D. Cohen
President
Information Builders

Moreover, at least two new markets are opening up for 4GL products. One of these markets taps a strong corporate interest in the decentralized use of company data. "Downloading information from mainframes to department-level and personal computing systems can be particularly efficient for users who want to pose only simple data inquiries," says Robert Roach, marketing director at Martin Marietta Data Systems. "Many people also want to deal with data when they need it, rather than waiting for access to mainframes," he adds. Thus, demand is growing for modified versions of mainframe-oriented 4GLs that can be used on mini- and personal computers.

The other new market takes advantage of a developing complementary relationship. "Our machines allow individuals to design software on a screen in much the same way as an electrical engineer designs a chip," says Ernest Allen Hershey, VP for advanced technology at Knowledgeware (Ann Arbor, Mich.), a vendor of systems development workstations. If, in addition, workstation commands are made compatible with the syntax of a particular 4GL, the transition from software design to programming instructions is made a lot smoother. Thus, says, Hershey, "we expect to see joint development and marketing arrangements with vendors of fourth-generation products in the near future."

—David H. Freedman

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IDENTIFICATION DIVISION.
PROGRAM-ID. SAMP1.
ENVIRONMENT DIVISION.
CONFIGURATION SECTION.
SPECIAL-NAMES.
    C01 IS TOP-OF-PAGE.
INPUT-OUTPUT SECTION.
FILE-CONTROL.
    SELECT INPT-FILE ASSIGN UT-S-INPT.
    SELECT SORT-FILE ASSIGN UT-S-SRT1.
    SELECT REPORT-FILE ASSIGN UT-S-OUTPT.
DATA DIVISION.
FILE SECTION.
FD INPT-FILE
    LABEL RECORDS OMITTED
    RECORD CONTAINS 60 CHARACTERS.
01 INPUT-REC     PIC X(80).
SD SORT-FILE
    RECORD CONTAINS 80 CHARACTERS.
01 SORT-REC.
    05 ACCOUNT-NUMBER          PIC X(5).
    05 ACCOUNT-DOLLARS         PIC $9(5)V99.
    05 FILLER                  PIC X(68).
FD REPORT-FILE
    LABEL RECORDS ARE OMITTED.
01 REPORT-RECORD                          PIC X(133).
WORKING-STORAGE SECTION.
01 FLAGS.
    05  FLAG-INPT              PIC XXX VALUES ZEROS.
        88 MORE-DATA           VALUE 'YES'.
        88 NO-MORE             VALUE 'NO'.
        88 FIRST-TIME          VALUE ZEROS.
01 COUNTS.
    05 LINE-NUMBER             PIC S99 VALUE +1.
    05 PAGE-NUMBER             PIC S999 VALUE +1.
01 PREVIOUS-ACCOUNT        PIC X(5) VALUE SPACES.
01 TOTALS.
    05 ACCOUNT-TOTAL           PIC $9(6)V99 VALUE ZERO.
    05 FINAL-TOTAL             PIC $9(6)V99 VALUE ZERO.
01 DETAIL-LINE.
    05 CARRIAGE-CONTROL        PIC X.
    05 ACCOUNT-NO-OUT          PIC ZZZZ9.
    05 ACCOUNT-TOT REDEFINES ACCOUNT-NO-OUT PIC X(5).
    05 FILLER             PIC XXX.
    05 ACCOUNT-TOT-OUT PIC $$$$,$$9.99.
    05 FILLER             PIC X(100).
01 HEADING-LINE.
    05 CARRIAGE-CONTROL        PIC X.
    05 FILLER                  PIC X(41).
       VALUE 'ACCOUNT                    TOTAL          PAGE'.
    05 PAG-NUMBER-OUT          PIC Z9.
PROCEDURE DIVISION.
PREPARE-SALES-REPORT.
        SORT SORT-FILE.
        ASCENDING KEY ACCOUNT-NUMBER
        USING INPUT-FILE
        OUTPUT PROCEDURE SALES-RPT THRU SALES-END.
    CLOSE REPORT-FILE.
    STOP RUN.
SALES-RPT SECTION.
    OPEN OUTPUT REPORT-FILE.
    PERFORM READ-RTN THRU READ-EXIT
    PERFORM PROCESS-INPUT THRU PR-EXIT UNTIL NO-MORE.
    PERFORM FINAL-PROCESSING THRU FINAL-EXIT.
SALES-END. EXIT.
PROCESS-INPUT.
    IF ACCOUNT-NUMBER IS NOT EQUAL TO PREVIOUS-ACCOUNT
        PERFORM ACCOUNT-TOTAL-PROCESSING THRU ACCOUNT-EXIT.
    ADD ACCOUNT-DOLLARS TO ACCOUNT-TOTAL FINAL-TOTAL.
    PERFORM READ-RTN THRU READ-EXIT.
PR-EXIT. EXIT.
READ-RTN.
    RETURN SORT-FILE AT END
        MOVE 'NO' TO FLAG-INPUT
READ-EXIT. EXIT.
FINAL-PROCESSING.
    PERFORM ACCOUNT-TOTAL-PROCESSING THRU ACCOUNT-EXIT.
    MOVE SPACES TO DETAIL-LINE.
    MOVE FINAL-TOTAL TO ACCOUNT-TOT-OUT.
    MOVE 'TOTAL' TO ACCOUNT-TIT.
    PERFORM LINE-OUT THRU LINE-EXIT.
FINAL-EXIT. EXIT.
ACCOUNT-TOTAL-PROCESSING.
    IF FIRST-TIME
        MOVE 'YES' TO FLAG-INPT
            MOVE ACCOUNT-NUMBER TO PREVIOUS-ACCOUNT
        ELSE
        MOVE SPACES TO DETAIL-LINE
        MOVE PREVIOUS-ACCOUNT TO ACCOUNT-NO-OUT
        MOVE ACCOUNT-TOTAL TO ACCOUNT-TOT-OUT
        PERFORM LINE-OUT THRU LINE-EXIT
        MOVE ACCOUNT-NUMBER TO PREVIOUS-ACCOUNT
        MOVE ZERO ACCOUNT-TOTAL
ACCOUNT-EXIT. EXIT.
LINE-OUT.
    IF LINE-NUMBER = 1
        MOVE PAGE-NUMBER TO PAG-NUMBER-OUT
        WRITE REPORT-RECORD FROM HEADING-LINE
            AFTER ADVANCING TOP-OF-PAGE
        MOVE SPACES TO REPORT-RECORD
        WRITE REPORT-RECORD AFTER ADVANCING 2 LINES
        MOVE 4 TO LINE-NUMBER
        ADD 1 TO PAGE-NUMBER.
    WRITE REPORT-RECORD FROM DETAIL-LINE
        AFTER ADVANCING 1 LINES.
    IF LINE-NUMBER = 55
        MOVE 1 TO LINE-NUMBER
    ELSE
        ADD 1 TO LINE-NUMBER
LINE-EXIT. EXIT.
```

SOURCE: INFORMATION BUILDERS

```
TABLE FILE SALES
SUM SALES AND COLUMN-TOTAL
BY ACCOUNT
END
```

RESULT

ACCOUNT	SALES
45452	$120.12
45453	$869.04
45632	$589.12
TOTAL	$1,578.28

Bottom: A table and the four lines of Focus 4GL code required to generate it. Top: The COBOL program needed for the same table.

are currently competing in this new market: Excelerator from InTech (Cambridge, Mass.), DesignAid from Nastec Corp. (Southfield, Mich.), and Information Engineering Workbench from Knowledgeware (Ann Arbor, Mich.). The software packages for each system sell for $5000–$10,000, and all run on the IBM PC family and compatibles (Nastec and Knowledgeware also offer mainframe components). Excelerator and DesignAid have each had modest sales of a few thousand copies; Workbench was just introduced. A fourth vendor, Cadre Technologies (Providence, R.I.), offers a similar product that runs on engineering workstations from Apollo and IBM. Such workstations cost about five times as much as an IBM PC/AT, but Cadre claims that the extra power lets its software handle larger and more complex projects.

Future versions of systems-design products promise what has become something of a holy grail in the software field: the capability to generate programs automatically when the system design is complete. Nastec is off to an early start, having announced in February a software bridge between its DesignAid product and the Gamma COBOL generator from Tarkenton Software (Atlanta). Although the bridge—which conveys system-level information to the COBOL generator—still requires a programmer to do some work directly with Gamma, Nastec claims that it will be fully automatic by year's end. Knowledgeware and InTech say they will soon announce similar bridges between their products and other COBOL generators.

While automatic bridges between systems-design workstations and COBOL generators are already appearing, it's not clear when, if ever, the COBOL generators themselves will be able to produce 100% of the necessary code with no programmer intervention. Smaller companies with simpler needs might be able to reach this goal within five years, estimates Paul Bassett, VP of research at Netron. But the generators may never be able to meet all the programming requirements of Fortune 500 companies, he says, because of the size and complexity of their typical applications.

Meanwhile, the systems-design workstation vendors are exploring various components based on artificial intelligence—such as products that suggest application designs according to the user's needs and predict the performance of each design—and program generator modules that offer a choice of programming languages. Other products might automate database design so that information is stored in the most efficient and accessible fashion, and might be able to assist companies in evaluating and planning their corporate-wide information requirements.

Assuming these promises are met, the fifth generation of programming languages may not be a language at all. It could be a tightly meshed medley of tools that "discusses" information needs with systems analysts and end users, finds or constructs the appropriate databases, and then writes the required code in the language of choice. □

David H. Freedman is a senior editor of Infosystems *Magazine.*

For further information see **RESOURCES**, *p. 69.*

NEW LIFE FOR STEEL

"Leapfrog" technologies may help U.S. steelmakers get the lead out

by Nicholas Basta

Steelmaking seems at first blush to be the smokiest of smokestack industries, and the one with the bleakest prospects. U.S. companies have lost $6 billion since 1982; shutdowns and mergers have been the rule of the day; and even as imports have cut into the low end of the steel market, plastics and other high-performance materials have cut into the upper end. Steelmaking capacity has dropped from a record 160 million tons in 1977 to about 130 million tons, with analysts predicting a decline to 120 million tons by 1990. Actual production has also fallen dramatically: Domestic companies shipped less than 80 million tons last year, a far cry from the 111 million tons shipped in 1973 and the 94-million-ton yearly average of the 1970s.

Still, steelmaking generates annual revenues averaging about $60 billion, making it the nation's fourth largest industry. And several sectors are relatively healthy. For example, "minimills"—plants that use scrap steel as raw material and make a limited line of fairly simple products such as wire rods and reinforcing bars—have steadily increased their market share, from 3% in 1960 to more than 20% last year. Minimills are less capital-intensive than larger "integrated" plants (so named because they begin with raw iron ore and produce a wide variety of steel products in annual capacities of a million tons or more). Specialty-steel plants, which make alloys and stainless steels with properties such as corrosion resistance and high strength-to-weight ratios, have also increased production in recent years. These plants share many of the economic advantages of minimills, and their products command top prices, accounting for about 10% of the industry's dollar sales while producing only 2% of its volume.

Despite the industry's current problems, therefore, some participants are cautiously optimistic about its future. For example, Donald H. Trautlein, chairman of both the American Iron and Steel Institute and Bethlehem Steel (Bethlehem, Pa.), predicts that by the mid-1990s the industry will be slimmer but stronger—and hence more competitive with Japan, West Germany, South Korea, and other nations in which steelmakers have aggressively built plants equipped with energy-efficient furnaces and automated metal-casting equipment.

Part of the industry's renewed vigor will result from incremental improvements in conventional factory operations; in fact, says Trautlein, many companies have already reduced their costs by as much as 20% in the last several years. But the most exciting talk in steelmaking circles concerns the development of "leapfrog" technologies that will enable U.S. companies to jump beyond the current state of the art to a new era of lower-cost, higher-quality products.

A survey of some of the industry's R&D efforts shows a ferment of new processes and techniques. For example, one goal is to convert integrated steelmaking, which is now a batch-production, capital-intensive technology, into a continuous, streamlined, and more versatile operation. New types of furnaces and metal-casting methods will further increase the efficiency of minimills and expand their product lines as well. And innovative production methods promise radically different molecular forms of steel and dramatically improved performance.

Modernizing metal melting. For integrated steelmakers, the traditional method of producing molten iron may be living on borrowed time. (Called "hot metal" in

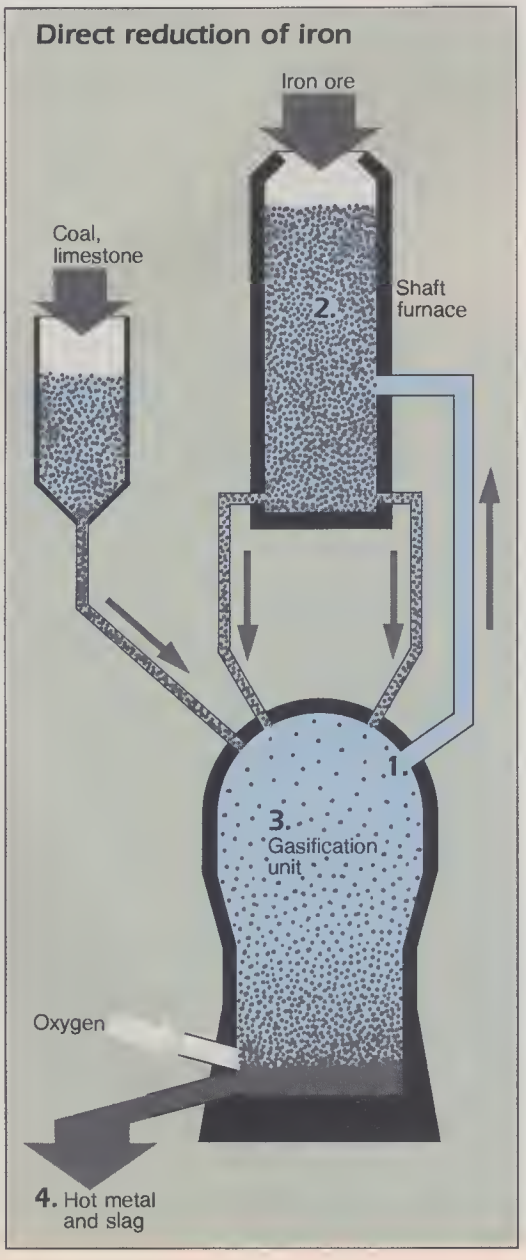
As cost and quality pressures mount, companies are increasingly turning to computerized process control. This system at Bethlehem Steel monitors width, gauge, shape, and temperature of strip steel being rolled.

the industry, molten iron is further processed into molten steel, which in turn feeds the metal-casting operations.) In a technique that harks back to the days of Sir Henry Bessemer, who developed the first commercial-scale steelmaking process in the mid-19th century, hot metal is made by mixing iron ore and limestone with coke in huge blast furnaces. Coke is a purified form of carbon that is made by pyrolizing coal in massive ovens; it serves both as a fuel for the furnace and as a source of carbon monoxide, which reacts with iron oxides in the ore to produce the hot metal. However, coke plants cost $100 million and are notorious sources of air pollution. Several companies are therefore considering a "direct reduction" method that uses ordinary coal rather than coke—the *Kohle Reduktion* (KR) process, developed by Korf Engineering of West Germany.

In the KR process, coal, limestone, and oxygen are mixed in a gasification unit, where 2500° F heat generates combustible gases. The gases rise into an overhead shaft furnace that contains iron ore, and they chemically reduce the ore to what's called sponge iron. The sponge iron then drops back into the gasifier, where it is melted and where the limestone reacts to remove contaminants. Finally, the hot metal flows out of the bottom of the gasifier.

Weirton Steel (Weirton, W.V.) and U.S. Steel (Pittsburgh) are separately angling for money from the Department of Energy to build a 300-ton-per-year KR plant to test the economic promise of the technology. Korf claims that a KR plant can be built for 25% less than a conventional blast furnace operation, largely because coking costs are eliminated. And U.S. Steel engineers calculate that the process can cut more than 15% off the production cost of hot metal. A federal decision about funding is not expected until mid-year at the earliest. However, Korf already has a 60,000-ton pilot plant running in Germany, and steelmakers in Japan, Brazil, and several European nations are interested in the process. South Africa's state-owned Iscor Ltd. is already building a 300,000-ton plant in Pretoria, scheduled to come on line by 1989.

For melting scrap—the sole source of molten steel in minimills and an important source in integrated plants—several approaches are being explored. For example, Intersteel Technology (Charlotte, N.C.) has developed a process called Consteel, which incorporates a specially designed electric furnace that can accept scrap continuously rather than in batches. Conventional electric furnaces have lids that must be removed each time scrap is added, and the furnace then needs several hours to reach temperatures high enough to melt the scrap. In the Consteel design, scrap feeds steadily through a tunnel-like insulated conveyor built into the side of the furnace, so it need not be "turned off." And to ensure that the furnace keeps running at its optimal temperature, scrap in the conveyor is preheated to 1650° F, largely by hot gases drawn from within the furnace. Molten steel is drawn from the bottom of the furnace through a spigot (in contrast to the conventional practice of removing the lid and tilting the furnace to pour the metal out). The metal can be tapped every 40 to 50 minutes, providing a steady supply that will allow downstream metal-casting operations to run closer to continuously. The furnace can keep producing hot metal up to six days straight before being shut down for routine maintenance.



Consteel can increase productivity by 150%, as well as save up to 30% on electricity and 60% on labor, according to John A. Vallomy, president of Intersteel and developer of the process. The improvements, he says, could knock $15–$23 off the $170 cost of making a ton of cast steel. As a result, says Vallomy, a 400,000-ton plant, retrofitted at a cost of $4 million, would pay for itself within a year. Consteel will make its commercial debut this year; Nucor (Charlotte, N.C.), one of the nation's leading minimill companies, is building a unit at its plant in Darlington, S.C.

Another promising scrap-melting process comes from Korf Steeltec, also in Charlotte. (Both Korf Steeltec and Korf Engineering were started by West German industrialist Willy Korf, but his relationship with Korf Engineering was severed in 1983.) Called the Energy Optimizing Furnace (EOF), it does away with electricity as a heating source. Instead, heat is generated chemically as carbon in the scrap and coal reacts with large amounts of injected oxygen. Natural gas burners heat the furnace initially, but they turn off once the temperature can sustain the carbon-oxygen reaction; the furnace then runs continuously for a week or more. Scrap is preheated by off-gases from the process in an overhead chamber and periodically drops through a vent into the furnace. Molten steel is drawn roughly every 70 minutes.

An EOF has been operating for several years at a Korf-affiliated mill in Brazil, Companhia Siderurgica Pains. John Bonestell, Korf Steeltec executive VP, says the furnace can be built for $10 million less than a conventional unit, and its energy savings can cut production costs by $19 per ton. Another

To eliminate costly blast furnace operations, steelmakers are considering the KR process, which uses coal rather than coke to convert iron ore into molten metal. In this simplified diagram, (1) coal, limestone, and oxygen react in the gasifier to form combustible gases; (2) the gases rise into an overhead furnace, where they chemically convert ore into sponge iron; (3) the sponge iron drops back into the gasifier and melts; finally (4) molten metal flows out the bottom.

attraction is that the EOF's cost/size ratio remains fairly stable, meaning that there is no economic penalty in building small furnaces rather than larger ones. This opens the door for building "micromills," which could have less than half the capacity of minimills and take better advantage of local market opportunities, says Bonestell. Korf plans to test the micromill concept this year by installing a 200,000-ton EOF at Connecticut Steel's plant in Wallingford, Conn.

Once molten steel is produced—by whatever means—contaminants such as sulfur and oxygen must be removed and alloying elements added as needed. Many steelmakers manipulate the chemistry while the brew is still in the melting furnace. But this can tie up the furnace for several hours, and a growing number of companies are recognizing that it is more efficient to transfer the molten steel into a secondary ladle as soon as possible. The steel can also be treated more thoroughly in ladles, allowing easier production of ultraclean, precisely tailored steels. A variety of so-called ladle metallurgy systems have been developed (HIGH TECHNOLOGY, Sept. 1983, p. 26). In some of the most advanced systems, the molten steel is cycled through a vacuum chamber, in which unwanted gases bubble off, and alloys and purifying materials such as calcium are injected into the ladle in the form of powders or wire rods.

Japanese and European steelmakers lead in applying ladle metallurgy. But U.S. companies are quickening their pace, spurred in part by the growing industrial demand for steels with improved and more uniform properties. And if domestic steelmakers adopt the new continuous furnaces, ladle metallurgy will be the only way to treat the steady flow of molten steel. "Perhaps one American mill in five now utilizes ladle metallurgy in some form," says Alan Smith, VP of Dravo Engineers (Pittsburgh), which installs systems developed by Nippon Steel. "Five years from now, most if not all facilities will be treating metal in the ladle."

Shaping to fit. When the molten steel, with the right metallurgy, cascades out of the ladles, a mill's work is only half done. The steel is then cooled to form ingots weighing up to 100 tons, which are processed into usable shapes such as rods, bars, and sheets. This has traditionally been done in a progressive series of hot and cold rolling operations, with each pass of the ingot through the rolls producing a thinner, longer product. However, steel researchers are working on methods to produce "near-net shapes"—that is, to cast the molten metal directly into forms fairly close to their final dimensions.

One such process, continuous casting, is already well on its way to becoming standard practice. Molten steel is poured directly from the ladle into special molds that shape the liquid into slabs roughly 10 inches thick. By skipping the ingot stage and several rolling operations, continuous casting saves $40–$50 per ton of slab. U.S. mills now run about 40% of their molten steel through continuous casters, lagging far behind the 86% level among Japanese steelmakers and 60% in Europe, according to a recent Department of Commerce survey. The cash-starved condition of many domestic companies retards conversion, but the industry is expected to reach the 60% mark by 1990.

The next leap in continuous casting will likely be to thin-strip casting, in which molten steel is formed directly into slabs that are only an inch thick. The slabs would be routed to a simplified rolling process to yield steel sheet roughly a tenth of an inch thick—the industry's most common product. Thin-strip casting will reduce a mill's capital costs and save enormous amounts of energy, and is expected to squeeze perhaps $45 from the $550 cost of making a ton of high-quality sheet steel, according to various industry estimates.

U.S. Steel and Bethlehem Steel lead in developing thin-strip casting. They are working together in the early stages of a five-year, $28 million project funded by the Department of Energy, with the companies each adding about $4 million of their own. A major part of the work involves modifying a machine that has been used for decades to cast thin sheets of nonferrous metals such as aluminum and copper. The machine, manufactured by the Hazelett Strip-Casting Corp. (Colchester, Vt.), casts molten metal at high speeds between two moving belts cooled by jets of water. Nonferrous metals are easily cast in this manner because they are processed at much lower temperatures and are more malleable than steel.

U.S. Steel experimented with the

BILL BARLEY

John A. Vallomy, president of Intersteel Technology, says his Consteel continuous scrap-melting process, now being adopted by Nucor, can reduce the cost of making cast steel by 10%.

U.S. mills are saving money and energy by running about 40% of their molten steel through continuous casters—such as this unit at Bethlehem Steel—which process hot metal directly into thick slabs.

Hazelett caster in the late 1960s, but the company had trouble feeding molten steel into the machine, and the finished sheets suffered from poor surface quality. However, ladle processing, which now yields molten steel that is cleaner and more uniform, is expected to make thin-strip casting easier. In fact, the current technology is deemed sufficient for producing steel sheet for use where surface quality is not of primary importance, as in construction. Nucor has already ordered a Hazelett caster for just this use; it will soon be installed in the company's Darlington minimill.

For the USS/Bethlehem project, Hazelett is now building two casting machines that will be installed in the companies' laboratories by the end of the year. One of the researchers' key modifications will be to fit the machines with an unusual molten-steel feeding system being developed by Westinghouse Electric Corp. (Pittsburgh). The system uses electromagnetic fields to stir the metal and produce a smooth, thin flow that should prevent the formation of surface flaws and irregularities in the grain structure.

Some specialty-steel companies are even farther along in devising thin-strip casting techniques for making their products. In late 1984, for example, Allegheny Ludlum Steel (Pittsburgh) announced that it had successfully cast molten stainless steel directly into sheet less than two-hundredths of an inch thick. "This development," says president Richard P. Simmons, "offers the possibility of dramatically changing the economics of producing thin stainless steel strip, and may open a number of new markets."

The company has spent $7 million on the project over seven years. Although details remain proprietary, Gerald Houze, director of research, says the key element is a rapidly spinning wheel that cools the sheets of molten steel on contact. The quick cooling causes steel crystals to grow unidirectionally—from the bottom to the top side of the sheet—while conventional casting triggers three-dimensional crystal growth. This causes no problems, says Houze, and Allegheny Ludlum is now trying to determine whether the unusual crystalline structure might impart valuable properties. The first sheet cast with the new process was about a foot wide, rolled into a continuous coil weighing 500 pounds. The company now plans to build a pilot plant in Lockport, N.Y., that will produce 10,000-pound coils in sheet widths up to about two feet, providing samples large enough to enable the company and its customers to evaluate the various stainless steels that can be produced.

Steel researchers hope to modify this Hazelett thin-strip caster so it can form molten steel directly into inch-thick slabs. It is now used to produce thin sheets of copper and other nonferrous metals.

Allied-Signal's Metglas has properties of both metal and glass, which make it especially promising for electrical applications. It's made by squirting a stream of molten steel at a rapidly spinning wheel.

Allied-Signal (Morristown, N.J.) has developed a similar technology, in which a stream of molten steel is squirted at a rapidly spinning wheel. The metal solidifies on contact into a thin ribbon, which shoots off the wheel at 60 mph and is coiled onto spools. The hot steel cools so fast—at a million degrees per second—that it has no chance to crystallize. The amorphous material thus shares many of the properties of both metal and glass; hence its name, Metglas. For example, Metglas resists corrosion like glass but has the electrical and magnetic behavior of metal.

Last July, Allied moved the Metglas operation out of corporate engineering and into one of its product divisions for commercialization. "In 1980 we were pricing Metglas at $300 per kilogram," says general manager Reed Belden. "Now it is $3.30 per kilogram." Metglas has already found a variety of limited applications; for example, it is used in photocopier printing units and in antitheft strips attached to various goods in department stores. But the company expects the biggest near-term volume to be in electrical steels, used widely in motors and transformers. Preliminary tests show that making utilities' transformer cores with Metglas can cut the usual power loss by up to 75%. (The Electric Power Research Institute estimates that the 25 million transformers in the national grid lose 12 billion kilowatt-hours annually.) Under EPRI sponsorship, Allied supplied 100 tons of Metglas ribbon to General Electric, which is building 1000 transformers at its Hickory, N.C., plant to be field-tested over the next year.

Along with developing new equipment and production methods, steelmakers are also increasing productivity by exerting tighter control over the operations in their mills. While steel

once lagged behind the chemical and petroleum industries in adopting computerized process-control systems, some people in the steel industry—such as Alan Smith, VP for technical services at Dravo Engineers—now claim that it has moved into a leading position. Yet some gaps remain in the sensors that monitor equipment performance and steel characteristics. As the National Research Council's National Materials Advisory Board recently reported, "The industry has need for better sensors that will operate continuously in high-temperature and other severe industrial environments, so that real-time measurements can be made and fed into on-line control systems."

To upgrade sensor technology, the American Iron and Steel Institute (AISI) is using funds from member companies to help underwrite a variety of projects at universities, federal and private laboratories, and the National Bureau of Standards. For example, researchers are working on sensors to meet the daunting challenge of determining the surface characteristics and internal temperature of steel as it zooms through rolling machines at speeds of up to 6000 feet per minute. They are also developing sensors for analyzing the chemical composition of molten steel while it is still in the furnace or ladle; samples must now be withdrawn and analyzed using benchtop instruments, a step that consumes precious time during the melting process.

Improved sensors promise considerable savings. AISI estimates that industrywide use of just one of the sensors being developed—a device that uses ultrasonic pulses to monitor the solid/liquid interface that forms as molten steel solidifies—will allow continuous casting machines to run more efficiently, producing energy savings and productivity improvements amounting to $275 million a year.

For cleaner, stronger steel, companies are using advanced ladle metallurgy systems. In this unit marketed by Dravo, the ladle is raised to a vacuum chamber (top), which draws off unwanted gases. Alloys and purifiers are then added in the ladle.

Future prospects. The National Materials Advisory Board report concluded that technologies like direct reduction, ladle metallurgy, and continuous casting "could help improve and maintain competitiveness, reduce capital costs for capacity additions, provide for smaller increments of added or replacement capacity, and accelerate the trend toward plants that are geographically distributed and produce specialized products."

But the problem is how to get there. Many companies today lack the necessary capital resources to carry out the research and build new facilities. As a practical measure, therefore, they have begun collaborating, pooling their individually modest resources into substantial funds. That this approach is already having an impact is shown in the latest annual report from Battelle Memorial Institute, which estimates that in 1986 the steel industry will lead all others in the growth of R&D spending, up 60.2% to $796 million.

"We know that breakthrough technologies like near-net-shape casting will have a profound effect on the industry," says James Collins, executive vice-president of AISI. "That's why we're working like hell to make progress in them, even though they won't reverse our financial condition next week or next year."

John Tumazos, senior VP of Oppenheimer & Co. (New York), points out that although "the infusion of new technology is a necessary condition for restoring the health of the industry, it is not by itself a *sufficient* condition. Past labor and management practices have left a lot to make up for." Nevertheless, a chastened U.S. steel industry is hoping that changes already made, such as reduced capacity, workforces, and overheads, have set it on the right track. "In recent years we've been through the worst of times," says Bethlehem Steel's Trautlein. "We may never see the best of times again, but I firmly believe better times are coming." □

Nicholas Basta is a New York–based science journalist.

For further information see **RESOURCES**, *p. 69.*

Minimills forge new strategies

Minimills are a leading user of advanced technology and one of the few profitable sectors within the beleaguered steel industry. The minimill is usually defined as a facility that makes steel from scrap using electric furnaces (it does not produce virgin steel from iron ore) and that generally has less than one million tons/year of steelmaking capacity. In addition, minimills tend to follow a nontraditional business strategy that emphasizes dependence on nonunion labor, low-overhead operations, and regional marketing of a limited spectrum of commodity products. By these criteria, there are about 60 minimills, owned by some 35 companies, in the U.S. today.

In spite of minimills' restricted product range—including reinforcing bars for concrete highway and building construction, simple beam or joist shapes, and wire rods—the low costs and aggressive marketing of such plants have pushed their share of the U.S. steel market from 3% in 1960 to over 20% at present (representing $15 billion in revenues), according to the U.S. Commerce Dept. In some product lines such as carbon-steel rods or bars, minimills command 90% of the current market. Leading companies are Nucor Steel (Charlotte, N.C.), Chaparral Steel (Midlothian, Tex.), and Quanex (Houston). Some secondary players have proven attractive to foreign investment: Korf Steeltec (Charlotte, N.C.) and Ellwood City Forge (Ellwood City, Pa.) are partly owned by West Germany's Korf Engineering and Sweden's Uddeholm Tooling, respectively.

Minimills are currently at a crossroads. "We are now competing heavily with each other," says F. Kenneth Iverson, chairman of Nucor. "There is some overcapacity in minimill products, and it is likely that this sector won't grow in the future as fast as it has over the past decade." As a result of these market conditions, Marathon Steel (Tempe, Ariz.), Soule Steel (Carson, Cal.), and Kentucky Electric Steel (Ashland, Ky.), among other companies, have closed their minimills in the past year. In addition, "big steel firms are becoming more competitive, introducing electric furnaces and pushing for lower labor costs," says William Hogan, director of the Industrial Economics Research Institute at Fordham University (New York).

Minimills are seeking to ensure continuing growth by improving their efficiency, upgrading their products, and uncovering new markets. "Growth is now a function of the types of products marketed, and the next big increment for minimills should be flat-rolled steel," says Arthur Blanchard, an industry consultant at Arthur D. Little (Cambridge, Mass.). Such steel is used in appliances, cars, office equipment, and many other applications; nearly half of all U.S.-produced steel is a variety of flat-rolled product.

But to produce flat-rolled steel, minimills would have to invest heavily in rolling mills that squeeze hot steel down to a fraction of an inch in thickness. The cost of rolling mills (up to $500 million) runs completely counter to the low-capital nature of minimills, and such installations would compete directly with existing rolling mills at the big steel companies. Thus, "entry into flat-rolled markets requires minimills to commercialize thin-strip casting technology, by which molten steel could be cast directly into thin sheets with a $20–30 million investment in equipment," says Peter Regan, VP at Hazlett Strip-Casting (Colchester, Vt.), a supplier of casting machines. "This technology should be in place over the next decade."

"If minimills don't keep up with new technology, they'll find themselves bypassed and forced to play catch-up, just like the integrated steelmakers. You can't afford not to keep pace."

F. Kenneth Iverson
Chairman
Nucor Steel

Minimills are also looking at other strategies. Quanex is tapping the $6 billion U.S. market for high-priced specialty steels in its new Fort Smith, Ark., minimill, which produces high-alloy steel bars used predominantly in oilfield operations. And Willy Korf, a German industrialist who ran a conglomerate of steel-related companies until the late 1970s, is currently planning to build a network of plants that would each produce less than 200,000 tons of steel annually. Such "micromills" would use new steel-melting technology (such as the Energy Optimizing Furnace) to produce inexpensive, low-grade steel used in local construction markets.

While these innovations may spark minimill growth, this sector is ultimately influenced by the same forces that affect the domestic steel industry as a whole. Many steel markets, for example, are threatened by the substitution of alternative materials such as plastics, aluminum, and composites, and overall consumption of steel has been flat or declining in many applications. However, the construction-materials business, a bread-and-butter sector for minimills, has shown sustained growth, according to John C. Tumazos, senior VP at Oppenheimer & Co. (New York). "While poorly capitalized companies may fall by the wayside," he says, "process improvements such as more automated equipment and advanced electric-furnace designs will contribute to overall profitability of minimills. Minimills are one of the few areas where there's any life in the steel industry." ***—Nicholas Basta***

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TENNIS RACKETS ENTER THE SPACE AGE

Composite fibers and computer-aided design are transforming an old sport

Tennis rackets have remained almost unchanged in composition and shape during the century-old history of the sport. But now, sporting-goods manufacturers are combining the same computer-aided design techniques used by Detroit automakers to engineer new cars, with materials technology pioneered by NASA. The result: longer-lasting, more powerful, and easier-to-control tennis rackets.

"There has been a series of technological breakthroughs involving materials, racket shapes, and control of string tension," says Leo Riley, national sales manager of Yamaha International (Buena Park, Cal.), which introduced a composite fiberglass racket back in 1974. Howard Brody, a physicist at the University of Pennsylvania and a dedicated amateur player, says that tennis is on the verge of sweeping changes: "We have really just begun experimenting on how to apply high technology to the sport."

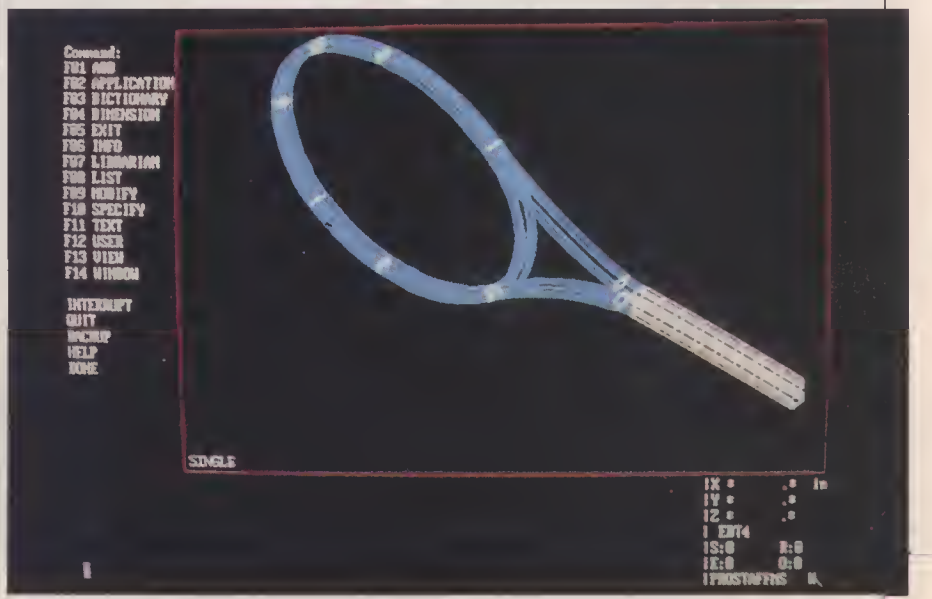
Although fiberglass rackets have existed for more than a decade, sporting-goods makers have only recently begun to combine fiberglass with other kinds of fibers—graphite and ceramics—in an attempt to make rackets lighter, stronger, and better able to absorb vibration. Last fall, Yamaha introduced a lightweight racket, the 90 Gold model, which uses a resin-bonded matrix of woven ceramic, graphite, and boron fibers together with fiberglass and Kevlar, a synthetic fiber made by DuPont. Wilson Sporting Goods (Chicago) also introduced a ceramic racket in Europe late last year and promises to have its domestic ceramic racket in U.S. pro shops by the summer buying season. Several other companies are also rushing to bring out ceramic models.

But ceramics, although impressive, are "just another material to put into a tennis racket," says Craig Robinson, engineering manager at Prince International (Princeton, N.J.). Robinson thinks that the way composites are constructed may prove to be more important than any one material. In pursuit of ways to structure a racket so that vibrations are dampened, for example, Prince's research is focusing on the ways different fibers and resins cross-link when bonded together in a thermoset, or hot melt, to form the racket's frame. The various composite materials—ceramics, graphites, or other synthetic fibers—are pressed into a resin film and then heated. As this mix warms, the different materials begin to cross-link, with bonds forming between the different molecules that tie them together, making them stronger. "It's like the vulcanization process for rubber tires," says Robinson, "only instead of adding a chemical, we do it with heat in the thermosetting process."

While structure may be primary in vibration control, the choice of materials affects other racket properties. So manufacturers are searching for the perfect mix of materials—the right composites that cross-link to produce both the lowest weight and the highest strength, while at the same time damping vibration. And although ceramics may be the current favorite, other space-age materials are equally promising. Kevlar, for example, is light enough to be used for high-performance yacht sails and tough enough for bulletproof vests.

Boron, another material in composite models, was first used by the aerospace industry in the late 1960s. Boron fiber composites are six times as stiff as steel and five times as strong as aluminum. But at $250 a pound, boron costs about five times as much as graphite, the most popular composite at present. Consequently, Prince's boron model is priced at more than $400, making it the most expensive tennis racket ever.

Racket makers are also investigating new frame designs. At Wilson, an Applicon Bravo CAD/CAM system is being used to develop tennis racket prototypes; this replaces the time-consuming and expensive method of constructing mock-ups. Among other things, "we're doing finite-element analysis that gives us a precise measurement of frame stress," says Bill Dillon, Wilson's assistant manager of



Sporting-goods maker Wilson uses both solid modeling and finite-element analysis to design new racket models.

by Michael Wendland

computer design. "And we've learned that just by redesigning the frame cross section, we can reduce the stress by 35%. That means rackets won't break so easily and they'll play better."

But no matter how advanced the materials or how sophisticated the design, the key to a racket's commercial success is how well it performs in the hands of a tennis player. Most players know from experience that their rackets perform best when the ball is hit consistently in an area close to the center of the strings, often referred to as the sweet spot. Rackets have not been designed with the sweet spot in mind, however, because it has heretofore been elusive. But Pennsylvania's Brody, who has done research for several of the major manufacturers, recently succeeded in giving the sweet spot some scientific definition. Using lasers and photodetectors to check vibrations and racket and ball motions, Brody found that there are actually three sweet spots:

- The first is where the shock felt in the player's hand upon striking the ball is minimized. That spot is known as the exact center of percussion, and it is most often found closer to the handle than the middle of the strings.
- The second sweet spot is where the racket vibrations are at a minimum. Rackets vibrate in several modes, depending on where the ball hits the strings. The fundamental mode oscillates at a low frequency (25–35 hertz) depending on the stiffness of the racket, but other, higher-frequency oscillations (harmonics) also occur, giving rise to annoying, buzzy vibrations that can be felt by the player and make the racket feel "rough." There is a point, however, where those vibrations cancel each other out. This "node" is typically located several inches above the center of percussion.
- The third sweet spot is the power point, where maximum rebound power is transmitted to the ball. It is measured by comparing the velocity of the ball before and after it hits the strings. The ratio of these two speeds—the "coefficient of restitution"—is usually highest closer to the throat (where the bow is joined to the handle) than to the center of the strings.

Brody's research presents a major dilemma to racket makers: The three sweet spots are in different locations, and none are in the center of the strings, where the ball is hit most effectively by the player. Nevertheless, he notes, the spots can be brought closer together by extending the strung area of the racket or changing the weight distribution of the racket head. Thus the oversized Prince rackets have brought the power point and the center of percussion closer, with a significant increase in performance. Similarly, some Wilson rackets have small weights on either side of the head to reduce vibration and twisting of the racket at impact.

The string tension of MacGregor's diagonally strung racket can be adjusted with a special key that fits into the base of the handle.

Another area of active inquiry involves stringing. Most tennis rackets use synthetic strings, as opposed to the more expensive, more resilient natural gut favored by professional players. But while some research is under way into finding a cheaper gutlike synthetic string, current interest centers on string tension, which can have a dramatic effect on a racket's playability. Because "power" players prefer tightly strung rackets while "control" players often specify lower tensions, no single racket can satisfy everyone. And regardless of preference, string tension decreases as the racket is played, necessitating frequent restringing. In an attempt to provide a racket for all players, MacGregor Sporting Goods (East Rutherford, N.J.) has developed a $250 model that features adjustable string tension.

The new MacGregor LongString was developed by Herwig Fischer, a West German aeronautical engineer and onetime tennis teacher, in cooperation with Lennart Bergelin, the former coach of Swedish tennis great Bjorn Borg. "It's not really the size of the racket but the length of the string that makes any spot on the racket sweet to hit," says Fischer. "For the elastic energy in the strings to be distributed nearly equally, the strings on either side of the ball should be nearly equal in length. But in conventional rackets, that's not possible unless you hit the ball perfectly."

The LongString racket has two strings, each 26 feet long, that are woven through the frame in an unusual diamond-shape pattern. The strings pass over individual nylon pulleys in the frame, which reduce the friction encountered on a conventional racket, where the string is drawn over the frame. The ends of the strings are fed down into the handle to a tightening mechanism that can be adjusted by a threaded bolt that fits into the butt of the handle. "When the ball hits the surface of the racket, the string actually moves," says Marvin Konowitz, general manager of MacGregor's racket division. "There is a trampoline effect that helps the ball stay on the racket longer, which gives you more control."

A similar racket called the Fine Tuner, recently introduced by the Austrian manufacturer Fischer Racquet, allows the player to adjust string tension by inserting a wrenchlike device into the end of the handle. "It used to be that you had to have a racket restrung to play different styles, or at least carry two rackets at different tensions," says Brody. "For a lot of players, being able to adjust your own tension can make the sport more playable."

All these developments—in materials, frame design, and stringing methods—are generally welcomed by tennis manufacturers as a way to increase player participation. But some experts think that technological improvements alone will not be enough. The industry is in trouble, they say, unless it concentrates on making rackets more affordable.

"It's easy to make a real expensive racket," says Drew Yuhas, product engineer at AMF-Head (Boulder, Colo.). "Today's composites are finished like a car, with a lot of colors, a lot of graphics, and a real fine surface finish. But that's very labor-intensive, and with all this comes a high price tag. So the big push has to be on keeping the costs down, and that's where technology has to lead us next." □

Michael Wendland is an investigative reporter for WDIV-TV in Detroit, as well as a freelance writer and author.

CLOSING IN ON SAFER VACCINES

The body's own defense system may hold the key to reducing legal and health risks

The recent knowledge explosion in immunology is giving birth to a host of new therapies for "tuning up" the human immune system. A growing number of these methods are based on special proteins called anti-idiotypic antibodies (or simply anti-ids)—molecules formed by the body through a series of reactions when challenged by a foreign cell or protein.

Anti-ids are now being eyed by several biotechnology companies as the basis of new vaccines that could ease some of the industry's longtime liability woes. The proteins might also be used to treat some forms of cancer, as well as disorders that appear to arise from immune-system malfunctions—such as myasthenia gravis and the severe type-I, or juvenile-onset, diabetes.

The anti-id concept still faces several limitations, however. One is that nobody is yet sure just when and how the proteins take part in the immune response. Another stems from both the infinite structural variety among the billions of antibodies produced during that response and the difficulty of plucking from this mixture the antibody with the desired therapeutic properties.

Still, future anti-id vaccines offer several advantages:

- Because the vaccines could be based entirely on harmless human proteins, vaccinated patients would not be exposed to live organisms. Even with the safest of today's vaccines, such organisms pose a small but distinct risk of infection.
- Targets against which an immune response is desired could be precisely selected, thus offering new flexibility and control in designing a vaccine.
- Anti-ids could be used in infants, defending them against certain diseases at a much earlier age than is now possible. Because the immune system is still relatively undeveloped during the first 18 months of life, infants are highly resistant to conventional vaccines.
- The vaccines might even immunize against organisms that do not provoke a normal immune response—the AIDS virus, for example.

Potential players in anti-id production and development include such immunology-based companies as Hybritech (San Diego), Cetus and Chiron (both in Emeryville, Cal.), and Centocor (Malvern, Pa.). And while most pharmaceutical companies do not break out their vaccine sales per se, the worldwide market is generally estimated to be on the order of $300 million a year.

The mammalian immune system is divided into two distinct but related networks: the cellular and the humoral. In the first, patrolling cells called macrophages and killer T-cells directly attack and destroy foreign bacteria or viruses. The second relies on a barrage of antibodies. These proteins, produced by white blood cells called B-lymphocytes, recognize and bind to their corresponding antigens—foreign cells or proteins, or specific parts of these invaders. The binding signals the destruction of the antigen by enzymes and other chemicals.

Such binding is possible because

BILL BRANSON/NCI

Antibodies—defensive proteins in the immune system—may lead to a new generation of vaccines. The National Cancer Institute's Robert Gallo (shown) has found antibodies against AIDS in a small number of the disease's victims, thus adding to hopes of an AIDS vaccine.

by Matthew F. Heil

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antigens have unique molecular projections, or "epitopes," that may serve as recognition and binding sites for one or more antibodies. The antigen is analogous to an extended hand, with the fingers constituting the epitope; an antibody binds to its epitope much as a glove fits over the hand. This binding occurs only at specialized, highly diverse parts of the antibody molecule called the idiotype. The rest of the molecule remains structurally constant.

Most vaccines are now prepared from either killed organisms against which immunization is desired or from closely related but harmless live strains. Of the two, a live organism is preferred because it induces a better immune response. Innocuous strains are not always available, however, so many vaccines are prepared from killed pathogens. The organism is first grown in large batches, then killed with heat or chemicals. The important thing is that the organism's geometrically unique epitopes are left intact; when injected into the patient, the epitopes trigger the formation of antibodies. The epitopes, moreover, are somehow "memorized" by the immune system, providing a lifelong line of defense against them.

But this procedure has several drawbacks. One is that an organism may survive the preparative procedures and actually infect the patient—a rare event that nevertheless has resulted in several deaths (and massive lawsuits) in recent years. Another drawback is that the methods for killing the organism can distort its critical epitopes and thus render it incapable of stimulating the necessary antibody production. And not all intact microbes elicit such antibody responses; important organisms such as the AIDS virus apparently can disguise their antigens or otherwise elude the immune system.

Such disadvantages have made vaccine marketing difficult and costly. In fact, industry sales have been relatively flat for the past several years, with many companies dropping out because of high liability costs. Connaught Laboratories (Swiftwater, Pa.), for example, got out of the DPT (diphtheria-pertussis-typhoid) vaccine business last summer because of difficulty finding an insurance carrier. That left Lederle (Pearl River, N.Y.) as the only American DPT vaccine producer.

The most appealing feature of anti-id vaccines is that their antigens are not foreign proteins but other antibodies. According to the network theory of immune regulation developed by Neils Jerne during the 1970s, the body produces not only idiotypic antibodies against a foreign protein but also anti-idiotypic antibodies against the first antibody, then anti-anti-idiotypic antibodies, and so on; each successive anti-id is the mirror image of its antigenic antibody. In 1981, two researchers—Brandeis University biologist Alfred Nisonoff and British immunologist I. M. Roit—proposed that since each anti-id was in effect an antigen, it could be used instead of natural antigens to trigger an immune response.

Anti-id vaccines are made by first injecting a lab animal with the antigen of interest (a strain of influenza virus, for example). After a week or so, the animal's antiviral antibodies are purified and injected into another animal. The second animal's immune system now produces anti-id antibodies to the first antibody; because of the mirror-image nature of the process, some of these anti-ids are structurally similar, or perhaps identical, to the original viral epitopes. If so, they should trigger an immune response to the virus.

The immune system does not fabricate just one type of antibody against the invader, however, but hundreds of thousands. Of those that attach to the various epitopes, only a very few neutralize the virus by binding to the epitope (or epitopes) that actually infects the host cell; the others attach to viral structures that play relatively small roles in infection. Identifying the single neutralizing antibody from this complex mixture—that is, pinpointing the "template" from which the anti-id will be produced—is for now a rather grueling trial-and-error proposition. (In essence, the trial consists of matching single antibody lines against the organism until a neutralizing line is found, then culturing the B-lymphocytes that produce only that antibody species.)

Although still in their early research stages, some anti-id vaccines already show promise. For example, a vaccine against hepatitis B is being developed at San Antonio's Southwest Institute for Biomedical Research by Gordon Dreesman (chairman of virology and immunology) and Ron Kennedy (chief scientist). Working with laboratory animals, the researchers have proved the viability of the process by binding some anti-ids to the virus; so far, however, they have not isolated the proteins that neutralize the organism.

Other diseases being targeted for anti-id vaccines include encephalitis, rabies, and polio. In the latter two cases, Hilary Koprowski at the Wistar Institute (Philadelphia) reports that the antibodies elicited by the vaccines were protective—that is, they neutralized the viruses and prevented infection in lab animals.

And in an especially timely development, weakly neutralizing antibodies have been found in a few AIDS patients by Robert Gallo, head of the laboratory of tumor cell biology at the National Cancer Institute (NCI) in Bethesda, Md. Like certain other organisms, the AIDS virus apparently camouflages itself during its invasion, thus stalling antibody production until after the infection has reached massive proportions. Gallo and his co-workers are trying first to learn how the virus sneaks past the immune system, then to decipher how and at what point the attack is finally mounted. Once armed with those facts, the NCI workers may be able to use the neutralizing antibodies, or others modeled after them, as the basis of an anti-id AIDS vaccine.

A possible competitor with anti-id products could be new vaccines based on synthetic polypeptides (small proteins) and recombinant DNA, now being developed by several biotech firms. This strategy also seeks to avoid the use of intact killed organisms, but by synthesizing only the epitopes needed for an immune response. Before the polypeptide can be synthesized, however, extensive information about the epitopes' chemical structure is required. (The anti-id versions can be made without such information.) Programs are now under way to develop synthetic vaccines for malaria (at Biogen in Cambridge, Mass.), gonorrhea (at Cetus), bacterial polysaccharides (at Connaught), and AIDS (at Chiron and at Molecular Genetics in Minnetonka, Minn.).

Another problem with synthetic vaccines, as with any of today's vaccines, is finding a form that will effectively immunize against the whole live pathogen. Anti-ids could be of some help here. Work by Koprowski and others suggests that, for unknown reasons, anti-ids combined with small doses of

synthetic antigen can help boost an immune response. Thus, instead of being in direct competition, companies seeking to make an effective synthetic vaccine may find anti-ids useful in the vaccine regimen.

Some new forms of cancer therapy also hinge on anti-id technology. For example, two Stanford University physicians—Ronald Levy and Richard Miller—are using the proteins to treat a form of cancer called B-cell lymphoma. The tumor in this case consists of malignant B-lymphocytes that carry idiotypic antibodies on their surfaces. Miller and Levy theorized that an anti-id antibody could be used to target these tumor cells and eliminate them, thus ridding the patient of the cancer. The Stanford team has so far tried its treatment on more than 20 patients. In at least one case, the anti-id apparently cured the cancer; tumors in several other patients have undergone partial regression.

Miller and Levy's company, Biotherapy Systems (Mountain View, Cal.), is among the first to be built primarily around the anti-id concept. (BioTherapeutics in Franklin, Tenn., is another that may tap the technology as a cancer therapy; see HIGH TECHNOLOGY, Nov. 1985, p. 79). Along with its work on lymphoma, says Levy, the company expects to pursue other anti-id applications, perhaps including vaccines.

Anti-ids might also serve as immune-system regulators for such disorders as type-I diabetes, lupus erythmatosis (an inflammatory disease of the skin and connective tissue), and the muscular disorder myasthenia gravis. In these and other "autoimmune" diseases, antibodies attack the individual's own cells. The diabetic's target cells, for example, are the insulin-producing beta cells of the pancreas, and at least some forms of arthritis may be due to antibodies attacking the joints' connective tissues. It may be possible to isolate these mutinous antibodies, then design anti-ids that will either destroy them or bind to them and render them harmless. Given the lack of other therapies for autoimmune disorders (which afflict more than 60 million people in the U.S.), the prospects of such treatments should be an important impetus for new anti-id treatments in the near future.

Even as such treatments near reality, however, it is clear that much remains to be learned about anti-idiotypes and their role in the immune system—how their production is finally switched off, for example. Vaccine researchers in particular also need new and faster tools for sifting through millions of antibody molecules to find the one of interest. Given the rapid growth of immunological knowledge in the past decade, and the growing recognition of immunology's importance to healthcare, it seems likely that many of these methods will soon become routine for treating—and even preventing—our most feared diseases. □

Matthew F. Heil is an immunologist and assistant professor of medicine at New York Medical College (Valhalla).

REDUCING EYE STRAIN

Better lighting and a variety of filters can ease the CRT's most glaring problems

JAMIE HOGAN

The lighting in a typical office is not kind to computer users. The most common office lighting—consisting of fluorescent fixtures near the ceiling that shine directly on the work area—is almost certain to wash out the screen and induce eye strain. Companies that spend thousands of dollars on computers, and even more on salaries, seem reluctant to take simple steps to improve the comfort and productivity of the people who operate the computers.

Screen glare, created by light reflecting off the glass CRT faceplate, can be addressed in two ways: by reducing the source of glare or by changing the screen. Sources of glare include not only lights and windows but also light-colored walls or even clothing opposite the screen. Whenever possible, the screen should be positioned at a right angle to the source of glare. In some situations, a strategically placed dark wall hanging or even a dark apron over a white shirt can help.

Adjusting office lighting isn't always easy. The challenge is to reduce the direct illumination on the screen while maintaining sufficient light on the work areas next to the computer. The best arrangement is to replace direct lighting with indirect lighting for the room, using smaller lamps on flexible arms for direct lighting on work areas but not on the CRT.

In a private office, you might simply leave the ceiling lights off and bring in new lights. But in shared offices, drastic changes in the lighting scheme are usually impractical. Blocking shades can help with ceiling lights, but installation is usually awkward, and if you move the computer, you must reposition the shade as well.

by Cary Lu

Offices with picture windows are another problem. Because most people would consider it a shame to give up the view simply to cut glare on their CRT screens, they should seek help through room dividers, light-filtering films for the window, and vertical louvers. The latter can reduce the light that reaches the computer while still leaving a view from elsewhere in the room; the more common horizontal venetian blinds restrict the view for everyone.

If you cannot control the light sources, you can shade the CRT screen with a hood or a deep shelf. The most effective design—devised by Laitram Corp., which is now looking for licensees—tilts the CRT far back under a bulky hood or a desk shelf; unfortunately, placing the CRT in a normal reading position requires a specially designed desk with a large inset.

Several optical companies advocate colored lenses in eyeglasses to improve screen contrast. These glasses are meant for use only with CRTs; you take off or change eyeglasses when turning to other work. For the average professional, who switches frequently from computer to paperwork and back again, such glasses are a nuisance; but for steady work at a CRT, such glasses might be worth looking into.

The other way to combat glare is at the screen itself—by selecting a CRT design that reduces glare. The flatter the CRT faceplate, the easier it can be positioned to avoid reflections. Most CRTs now have a roughened glass faceplate that scatters reflected light and thus reduces glare. Such surfaces also degrade the image a little, however, and the highest-resolution CRTs tend to have less roughening and thus potentially more glare.

In most situations, an antiglare filter over the CRT screen helps greatly, even when the lighting is nearly perfect. The ideal filter would eliminate

screen glare, add no glare itself, preserve the screen brightness and resolution, and be easy to install and clean; it should also be inexpensive. But no filter meets all these requirements.

The poorest antiglare filter simply adds roughening—a plastic sheet with an etched surface and perhaps green or amber color filtration as well. These cheap filters are essentially disposable but have little else to recommend them. (And no one has demonstrated that green or amber screens are actually any better than white; for many graphics applications, white is the obvious color because of its correspondence to paper.)

Louvered screens, now rare, control glare with tiny parallel light-blocking strips that work like miniature venetian blinds. They force you to look at the screen from a narrow angle of view—a nuisance most of the time—and resolution and brightness suffer.

Mesh screens (under $25) are the most common antiglare filters. A typical mesh screen transmits about 40% of the light. The mesh cuts glare by breaking up the reflections, but resolution suffers, even with the finest mesh. Nevertheless, mesh filters do help in many situations, particularly for text-only displays where resolution degradation is not a major problem. The mesh itself creates some new reflections, although these are usually not severe.

The most effective antiglare filters use optical coatings of the type found on camera lenses. The simpler designs use a neutral-density filter combined with an antireflection coating. The filter (typically 30% transmission) cuts the ambient light reaching and reflecting from the CRT faceplate, while the coating suppresses reflection by the filter itself. OCLI, Vu-Tek, and Hoya make simple antireflection filters using multiple layer coatings. The cheapest ($35), from OCLI, uses Mylar and scratches easily. At $60, the OCLI Vantage filter uses a single sheet of tempered glass, while the Vu-Tek filter uses a fairly hard plastic. The $99 Glare/Guard Professional filter from OCLI is also made from tempered glass, and has a grounded conductive coating that reduces the dust problem created by static electricity on CRTs. The $129 Hoya Anti-Glare screen includes a shallow hood.

A second filter type circularly polarizes the ambient light striking the CRT faceplate; upon reflection, the light's polarization is reversed and will not pass back through the filter. The polarization process also cuts light transmission, so such filters function as neutral-density filters as well, typically with 32–38% transmission. Because CRT faceplates with roughening tend to depolarize the reflected light—thereby reducing a circular polarizer's efficiency—the trend to smoother faceplates on high-resolution screens could make circular polarizers more desirable.

In Laitram Corp.'s concept, glare is cut by tilting the screen and placing it under a hood or shelf.

Both Polaroid and Vu-Tek make circularly polarized filters. The cheapest, the $50 Polaroid CP-50 (sold also by Kensington Microware and others), uses a relatively soft plastic that scratches easily during cleaning. The more expensive Polaroid CP-70 ($129) and Vu-Tek ($119) are made from laminated optical glass.

Any coated optical surface is more fragile than an uncoated glass CRT. Thus all the antireflection-coated filters require operational changes. They must be cleaned carefully with lens cleaners, and users accustomed to pointing at the screen with their fingers must break the habit, since fingerprints mar the image severely. The flat plate of the filter will reflect strong light sources despite the coatings, so the screen may need minor repositioning to eliminate windows or lights in the reflected viewing axis.

Both the simple antireflection and the circular polarizing filters work well. In typical situations, neither type has a clear advantage over the other; the differences rest in relatively minor variations in light transmission, coating, and mounting technique. Careful comparative tests of these two antiglare screen types (such as published by Robert Morse in the *Proceedings of the Human Factors Society,* 29th meeting, p. 782) found only small differences that would be outweighed by minor adjustments to lighting and screen angle.

Because these filters all reduce the light transmission, screen brightness must usually be turned up, potentially shortening the life of the screen. This shouldn't cause any problems in normal operation, but it might be sensible to install software that automatically turns off the screen when the computer is not in use. For the IBM PC, the keyboard enhancers ProKey, SuperKey, and Keyworks all include a screen-saving feature; for the Apple Macintosh, Accessory Pak 1 from Silicon Beach Software includes a screensaver function. The screen is restored by pressing any key (preferably the shift key, to avoid sending an accidental keystroke), or by clicking the mouse button on the Macintosh.

If these antireflection measures are so effective, why aren't they incorporated into the CRT itself? After all, bonding the antireflection filter to the screen works better than adding one later, because it gets rid of two air-to-glass surfaces that can generate more reflections. Several high-end CRTs from IBM, DEC, and other companies do in fact come with integral antireflection coatings made by OCLI, but so far the additional costs have proved to be a barrier for most microcomputer manufacturers. □

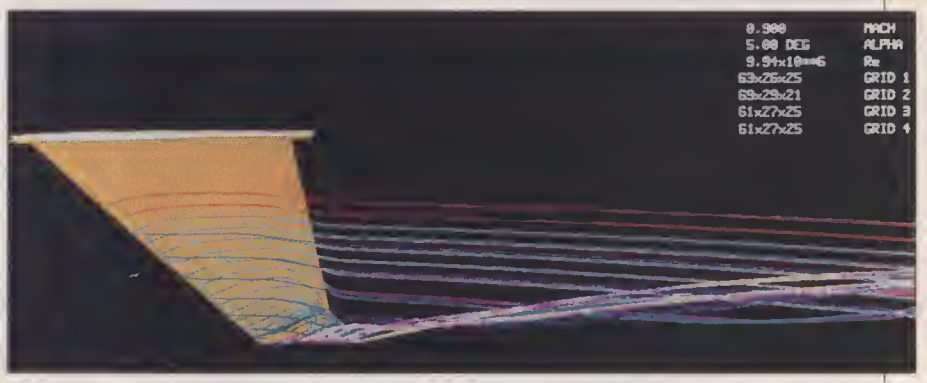
Companies

Laitram, PO Box 50699, New Orleans, LA 70150, (504) 733–6000
Optical Devices (Vu-Tek), 805 Via Alondra, Camarillo, CA 93010, (805) 987–8801
Optical Coating Laboratory Inc. (OCLI), 2789 Northpoint Pkwy., Santa Rosa, CA 95401, (707) 545–6440
Polaroid, Polarizer Division, 1 Upland Rd., Norwood, MA 02062, (617) 446–4503
Uniphot (Hoya filters), 61-10 34th Ave., Woodside, NY 11377, (718) 779–5700

Cary Lu is microcomputer editor of HIGH TECHNOLOGY.

AVIATION INDUSTRY'S AERODYNAMIC DUO

The marriage of supercomputers and wind tunnels is revolutionizing aircraft design



Streamlines calculated by the Cray-XMP supercomputer at NASA's Ames Research Laboratory reveal airflow past the wing of an F-16 flying near the speed of sound.

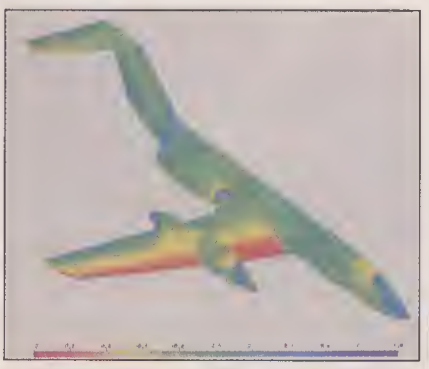
A new technology, the supercomputer, is working in tandem with an old one, the wind tunnel, to change the way engineers design aircraft. Because supercomputers operate cheaply and flexibly, they provide far more scope than ever before to study innovative designs—the most promising of which may then undergo traditional wind tunnel tests.

Pioneered a decade ago by NASA, the combination of computerized aerodynamics and wind tunnel testing has developed relatively slowly because of the vast complexity of air movements around aircraft in flight. Even the best programs available today cannot routinely simulate situations more complicated than straight and level flight through smoothly flowing air. But broader simulations are emerging, and even now several aerospace companies are using computational aerodynamics as a basic design tool.

Boeing, for example, uses computational methods alone for about 80% of its effort to design airliners' wings. The company also enlisted its Cray-1 supercomputer to redesign the exhaust nozzles of the 747's engines, thereby gaining a fuel saving of 0.6%. Modest as that may seem, it should save $75,000 a year for every 747 in service.

Boeing's Cray-1 also helped to solve a fundamental problem that had puzzled aerodynamicists for two decades. Airliners' engines are housed in nacelles, which attach by struts to the wings' undersides. The struts should be as short as possible (both to save weight and to reduce the length and weight of the landing gear), but wind tunnel tests established that drag increased unacceptably when a nacelle was too close to the wing. Those tests could not show the origin of the drag, however. The Cray-1 enabled engineers to determine that the weight of the nacelle and strut caused local disturbances in the wing's airflow, which then induced drag. The cure was to spread this weight over more of the wingspan, using a new nacelle and a short, lightweight strut. The result has been particularly efficient engine installations for Boeing 757, 767, and 737-300 jetliners.

Beyond localized "sweetening" of subsystems, computational aerodynamics has also improved the overall performance of successive models of existing aircraft. Designers at Grumman Aerospace used an IBM 3083 mainframe, whose power can approach that of a supercomputer, to develop new wing cross sections in the Gulfstream series of business jets. As a result, the Gulfstream III had a lift-to-drag ratio 26% greater than that of its predecessor. Its range increased from 2700 to 3700 nautical miles, while its speed rose from Mach 0.75 to Mach 0.78. The Gulfstream IV incorporates further advances: a range of 4300 nautical miles and a speed of Mach 0.80.



Colors in a Lockheed-Georgia simulation show varying pressures of airflow around a Gulfstream GII jet wing.

But what has aerodynamicists most excited is that supercomputers have proved essential for designing two "airplanes of the future"—the supersonic-combustion ramjet ("scramjet") and the X-wing. Engineers have long recognized that the scramjet theoretically possesses enough power to fly directly into orbit (HIGH TECHNOLOGY, Dec. 1985, p. 62), but no wind tunnels existed that could test engines at such speeds. Supercomputer simulations sponsored by NASA and the Defense Advanced Research Projects Agency at Boeing, Lockheed, and McDonnell Douglas have lately made the needed confirmations. The X-wing is a jet-powered helicopter whose rotor can stop in midair to form a cross-shaped wing (HIGH TECHNOLOGY, Nov. 1985, p. 68). This wing must generate lift by injecting thin sheets of air through slots just above its leading and trailing edges. Supercomputers at Sikorsky and Lockheed-Georgia have worked out the sequence of action for the air sheets, and wind tunnel tests have confirmed that the complete X-wing works as planned.

Predicting the lift, drag, and stability of aircraft requires knowledge about basic features of the airflow, including pressure distributions, the formation of shock waves, and the pres-

by T. A. Heppenheimer

SCIENCE/SCOPE®

Following seven years of deliveries that were on time or ahead of schedule, Hughes Aircraft Company has completed production of the electronic "brains" for the U.S. Navy's Trident I Fleet Ballistic Missile. The guidance electronic assemblies incorporate advanced technology to withstand harsh operating conditions underwater and in space. Since 1978, Trident guidance assemblies containing Hughes electronics have performed flawlessly in 50 test launches. This reliability record follows outstanding performances established by Hughes in the past 25 years on the Polaris and Poseidon programs. Fabrication of development guidance electronics flight hardware has begun for the Trident II missile.

The U.S. Department of Defense has given two of its four top money-saving awards to Hughes for proposals that will cut costs by nearly $275 million. The Contractor Value Engineering Achievement Awards honor defense contractors for helping to trim defense costs during 1984. The Air Force cited Hughes for saving $172.8 million on the Imaging Infrared Maverick air-to-surface missile over the life of the contract. The Navy honored the company for reducing projected costs on the UYQ-21 data display system by $101.5 million. Hughes also contributed to the savings achieved by FMC Corporation, which won the Army award for cost-cutting efforts on the Bradley Fighting Vehicle System. The Value Engineering program was created to cut production costs without affecting performance, reliability, quality, maintainability, and safety standards. The armed forces approved 34 Hughes VE proposals for total cost reductions exceeding $296 million. Since 1964, Hughes military customers have approved 705 changes on 52 programs for total savings of $887 million.

Telecommunications via satellite continue to bring Indonesians closer together by bridging the thousands of islands of their nation. In 1976, Indonesia became the first nation after Canada and the United States to operate a domestic geosynchronous communications satellite system. Long-distance telephone traffic more than tripled in the first five years and continues to grow. New Palapa-B satellites have improved the quality and efficiency of services while expanding coverage into Papua New Guinea and into smaller communities and outlying areas of Indonesia. The increased power of the Hughes satellites allows ground stations to use antennas 3 to 4.5 meters in diameter, as opposed to the 10-meter antennas at all the original stations.

Advanced computers give North America's new air defense system more capability at a fraction of previous operating costs. The Joint Surveillance System (JSS), developed for the U.S. Air Force by Hughes, watches over the entire United States and Canada from eight regional operations control centers. The system is controlled by nine Hughes 5118 ME central computers, each with 500,000 words of memory and capable of performing 1 million operations per second. These computers, in turn, direct seven Hughes HMP 1116 peripheral computers to perform subordinate tasks. The system provides its own back-up whenever faults are detected. Because the system requires less staff and maintenance than the previous system, JSS saves over $100 million a year in operating costs.

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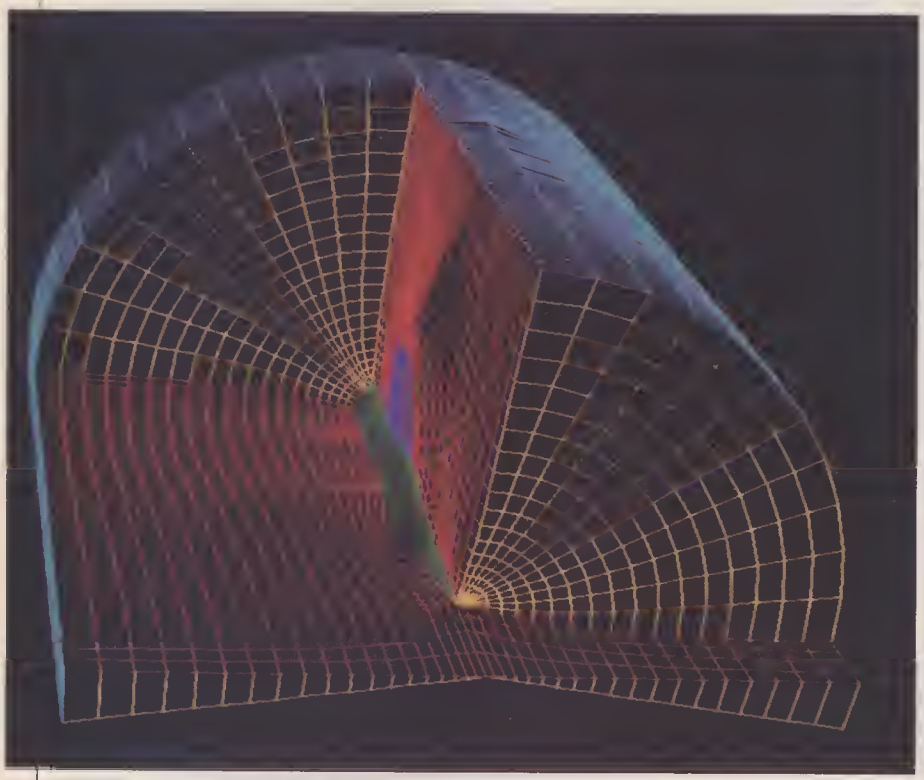


This cutaway grid around an F-16 is the starting point for an aerodynamic simulation at NASA Ames. The Cray-XMP calculates pressures at each intersection.

ence of vortices and regions of turbulent flow. While many of these features can be roughly estimated by engineering calculations, the best approximations have come from wind tunnel work, in which a physical model of an aircraft or wing is immersed in a stream of high-speed air. Force-measuring instruments determine lift and drag, probes in the airflow measure pressure or velocity, and specialized optical techniques reveal shock waves and turbulent wakes.

Computational aerodynamics can achieve this through mathematical models and computer simulation. The aircraft's shape is stored as a set of coordinates to which the computer fits curves or surfaces to define the aircraft's boundaries. Under simulated environmental conditions, it solves the equations of motion for fluid flow—at each point and for each instant of time—subject to the condition that the airflow can neither penetrate nor emerge from the defined boundary.

The equations stem from Newton's laws—the formulations that allow calculation of the trajectory of, say, a spacecraft in orbit. In a sense, the fluid-flow counterparts of Newton's laws calculate the trajectories of particles of air as they stream past aircraft. A single solution of the equations—known as the Navier-Stokes equations, after their discoverers—gives values for the pressure, density, and velocity of the airflow at each of numerous points near the aircraft. From these data, standard mathematical techniques can calculate lift, drag, patterns of shocks, and the onset of turbulence.

In principle, a computer can produce simulations that capture as much detail within a flow, over as large a portion of an aircraft, as any engineer would wish. But in reality, even the most powerful supercomputers run into practical restrictions imposed by limits on their speed and memory.

The problem arises from the complexity of fluid flow. The smallest significant turbulent swirls or eddies, for example, are 10,000–100,000 times smaller than the largest. A solution that could capture the complete intricacy of the flow over an airplane would yield only to a computer with the power of a billion Cray-1s, according to Victor Peterson, director of aerophysics at NASA's Ames Research Center (Mountain View, Cal.). Thus, today's computations are restricted to the simplest situations—that is, straight and level flight in which the air flows smoothly.

Even those conditions demand highly complex programs. One example is a program called FLO 57, written by Antony Jameson, professor of aerospace engineering at Princeton, for analyzing uniform, nonturbulent conditions. FLO 57 has to accommodate 100,000 points on and near the aircraft, and repetitively solve the fluid-flow equations throughout this entire grid. About 500 iterations, each requiring some 100 million floating-point operations, may be necessary until the calculated values no longer change appreciably with further computation. The complete solution, which gives values for pressure, density, and velocity at each of the 100,000 points, thus requires some 50 billion operations.

Moreover, such computer codes are not user-friendly. "You need the guys who wrote them, or who have been running them for ten years," says Robert Coltrin, head of the supersonic and hypersonic aircraft section at NASA's Lewis Research Center. "It takes a real expert to adapt a program to the next situation." Simpler codes are fully documented and ready for use—they are available from NASA's Computer Software Management and Information Center at the University of Georgia—but they are limited to, say, wing design for transport aircraft over restricted ranges of speed.

By contrast, FLO 57 holds at all speeds, and also treats fighters, whose wings are shorter and whose fuselages have complex shapes. But FLO 57 works only for smooth flight. Airflows in turbojets, aircraft buffeted in rough air, airplanes nearly stalling in the normal process of coming in to land, and maneuvering fighters all involve

problems with turbulent airflow. As Andrew Srokowski, coordinator for independent research and development at Lockheed-Georgia, puts it: "If you take an F-16, crank it up to a 30° angle of attack, and put some sideslip on it, you've got some pretty complicated phenomena."

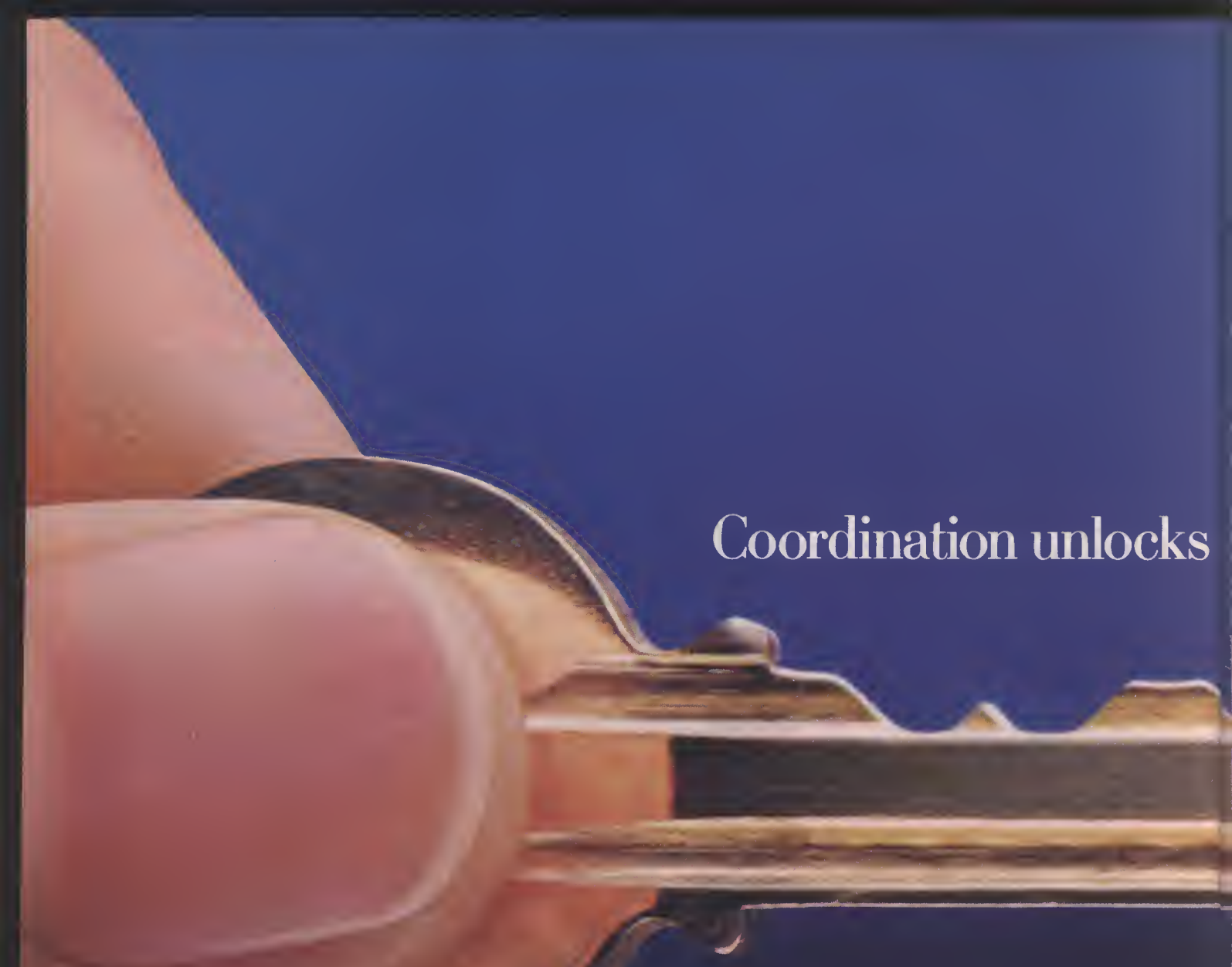
No program in routine use today can simulate such flows. And they are very difficult to generate in a wind tunnel. But there is a fluid flow model, called the Reynolds-averaged Navier-Stokes equations, that can handle such problems. It includes all the factors from the Navier-Stokes equations, but does not calculate finely detailed and rapidly varying turbulent eddies. Instead, the model introduces terms that represent the average turbulence. However, the Reynolds-averaged Navier-Stokes equations for a complete airplane demand ten to a hundred times more computer power than FLO 57, according to Peterson.

Not surprisingly, progress in Reynolds-averaging has been slow. No code comparable to FLO 57 is in general use in the aircraft industry, even for as simple a case as a two-dimensional wing section. The closest approach is a proprietary program from Lockheed-Georgia that designers have applied to such problems as the X-wing aircraft. Called MANS, for Multiple Airfoil Navier-Stokes, the program took eight years to develop. It can treat airflow over a complex airfoil with a leading-edge slat and a two-part flap. It can also deal with a simple three-dimensional wing, although such a wing with slats and flaps is beyond its scope.

To encourage work in this area, NASA's Ames Research Center last year established the Numerical Aerodynamics Simulator. The laboratory's goal is to demonstrate the routine use of Reynolds-averaging in the computation of flows, over nothing less than entire aircraft. In order to achieve this, the strategy of NASA managers is to acquire the newest and most powerful supercomputers as soon as they are available. In September 1985, for example, Ames became the second lab—after the Lawrence Livermore National Laboratory—to install a Cray-2. This supercomputer has a sustained speed of 250 million floating-point operations per second (Mflops) and main memory of 256 million words; it can reach a peak speed of 2000 Mflops for short periods. But by 1988, NASA expects to have a new machine capable of a sustained speed of 1000 Mflops, and possibly a billion-word memory. Candidates include the Cray-3, whose design is well under way, and the GF-10, being developed by ETA Systems, an entrepreneurial division spun off from Control Data. (The "10" in its designation represents a peak speed of 10,000 Mflops.) During the 1990s NASA intends to achieve a sustained speed of 4000 Mflops and a central memory in excess of a billion words.

But even after such machines are in use, computational aerodynamics will still have far to go. It won't reach full maturity until the shapes of complete aircraft can be routinely treated using the most realistic flow models, which capture the full complexity of turbulence. The only practical models, says NASA's Peterson, are those based on the Reynolds-averaged Navier-Stokes equations, which demand supercomputers a thousand times more powerful than the Cray-3 and GF-10. If computer design continues at its present pace, he says, such machines should emerge in about a quarter century. Come 2015, if present forecasts prove accurate, new aircraft and their engines may be designed entirely by supercomputers. □

T. A. Heppenheimer, a writer based in Fountain Valley, Cal., holds a doctoral degree in aerospace engineering.



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PERSPECTIVES

Japanese design jets for the short haul

Japanese government and industry are collaborating on jet airplane technology tailored to Japan's crowded island environment. The techniques under development could eventually prove superior to conventional approaches for short-haul aircraft, say officials, even in places where few of Japan's restrictive conditions exist.

The vehicle for these hopes is the experimental QSTOL (quiet short takeoff and landing) plane. The first large jet entirely designed and built by the Japanese—Kawasaki, Ishikawajima-Harima, and Mitsubishi are the major contractors—it underwent its maiden test flight last October. Called Asuka (flying bird), and based on a domestic C-1 jet transport airframe, it can fly at Mach 0.7 with a ceiling of 30,000 feet and a maximum range of 1000 miles. In its seven flights to date, the craft has shown its basic airworthiness but has not been required to undertake short takeoffs and landings.

The key to Asuka's STOL capability is the location of its four FJR710 turbofan engines. They are mounted above the forward part of the wings so that their exhausts blow directly across the wings' upper surfaces. Upper surface blowing (USB) takes advantage of the Coanda effect—the tendency of a stream of air or other gas to follow the curve of the surface across which it is moving. If the rear edge of the wing curves down sharply, as it does when a plane's flaps are lowered for takeoff or landing, the airflow makes a corresponding sharp downward curve after it has passed over the wing. This creates an opposing upward force, or lift, on the wing, enabling a plane using USB to remain airborne at lower speeds than one relying on airspeed alone. Alternatively, it can use smaller wings, which increase efficiency at cruising speeds by decreasing drag.

Since the exhaust outlets lie above the wings, much of the engines' sound is deflected upward. Thus relatively little noise reaches nearby areas on the ground during takeoff and landing. The plane's rapid ascent and descent—it can reach a height of 35 feet in 2230 feet of horizontal travel from a standing start and can descend to a dead stop from the same height in 1574 feet—reduces noise levels further. And the engines are relatively quiet, because their bypass ratio (the amount of air routed around the combustion chamber versus the amount sent through it) is 6:1, as opposed to the 1:1 ratio of conventional turbojet engines.

Japan's QSTOL plane Asuka undertakes an early test flight. It obtains extra lift from the engine exhausts blown over the upper surfaces of its wings.

USB is not problem-free, however. At the low speeds at which the plane is designed to fly, the flow of air decreases over the non-USB area of the wing, causing the airflow to separate from the wing surface. This reduces lift and makes control surfaces less effective. To address this problem, designers have devised a boundary layer control system, in which compressed air is bled from the engines and forced out through small holes in the leading and trailing edges of the wing. Additionally, the plane's leading-edge slats and ailerons have been modified to yield a larger droop angle, and thus more lift.

Another problem is that Asuka's flying characteristics differ considerably from those of conventional planes. Increasing its engine thrust intensifies lift but actually decreases speed. To increase speed, the pilot must reduce drag by lowering the pitch attitude (the fuselage's inclination to the horizontal). Decreasing engine thrust can cause the plane to stall even if it maintains its speed.

Because flying Asuka would obviously be confusing for pilots accustomed to conventional planes, its developers have installed a stability and control augmentation system (SCAS), consisting of a main computer and two backups, to control virtually all aspects of flight in response to the pilot's input. On takeoff and landing, for example, SCAS adjusts the engine thrust and control surfaces to attain the correct angle of climb or descent automatically. As a result, says Masataka Maita, senior research official at Japan's National Aerospace Laboratory, the plane is actually easier to fly than conventional aircraft.

But what if SCAS fails? Pilots are undertaking intensive training in simulators to enable them to handle such an emergency. "The airplane is not that difficult to fly without SCAS," says Dennis Riddle, head of a STOL project at NASA's Ames Research Laboratory that has exchanged data and pilots with the Asuka team.

In any case, notes Maita, Asuka is not a prototype for a commercial aircraft but a "flying research laboratory" to help develop a new Japanese technology base and give domestic manufacturers some experience in building such airplanes. □ ***—Bob Poe***

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RESOURCES

Information sources for topics covered in our feature articles

Electronic publishing, p. 18

Contacts

Cahners Exposition Group, 999 Summer St., PO Box 3833, Stamford, CT 06905, (203) 964–0000. Holds Corporate Electronic Publishing conference in a different location each year. Conference includes seminars on industry issues and exhibits by major system vendors.

Computer Publishing Systems Market Requirements Service, C. A. Pesko Assoc., 1 Snow Rd., Marshfield, MA 02050, (617) 837–1341. For a $12,000 annual fee, clients receive information on product specifications, market analysis, and technology, as well as newsletters covering new products.

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Desktop Publishing. User Publications, PO Box 5245, Redwood City, CA 94063, (415) 364–0108. Magazine, 6 issues/yr. $24.

Personal Publishing. Renegade Co., PO Box 390, Itasca, IL 60143, (312) 250–8900. Monthly magazine. $30/yr.

Tomorrow's weather, p. 27

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Amer. Meteorological Soc., 45 Beacon St., Boston, MA 02108, (617) 227–2425.

National Council of Industrial Meteorologists, 8801 Fox Dr., Thornton, CO 80229. Contact: Loren Crow of Loren Crow Consultants, (303) 753–6500.

National Weather Service/NOAA, 8060 13th St., Silver Spring, MD 20910, (202) 427–7622.

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TECHSTARTS

Xilinx:
PROGRAMMING SEMICUSTOM CHIPS

In order to shorten the many months it can take to create custom-designed microchips, semiconductor manufacturers have devised "semicustom" chips. Many of these contain an array of rudimentary circuits that users can mix and match to create a unique design, usually by destroying connections to unwanted circuits. Xilinx's new twist is to configure a design from data stored in a memory element housed on the chip itself. Because circuit connections need not be permanently destroyed, users can reprogram chips simply by feeding new data into the memory element. Semicustom chips are a growing but increasingly competitive segment of the semiconductor market, already populated with such companies as LSI Logic and VLSI Technology.

Financing: $12.5 million in venture capital financing from Berry Cash Southwest Partnership, Interfirst Venture, InterWest Partners, Matrix Partners, Morgan Stanley, Rainier Venture Partners, Hambrecht & Quist, Kleiner Perkins Caufield & Byers, and J. H. Whitney.

Xilinx's strategy, says president Bernie Vonderschmitt, is to store design data on the chip itself.

Management: Bernie Vonderschmitt (president), James Barnett (VP of administration and strategic planning), and Ross Freeman (VP of engineering) left semiconductor manufacturer Zilog to found the company. Vonderschmitt was VP and general manager of Zilog's component division, Barnett was a product line director, and Freeman was the component division's director of engineering.

Location: 2069 E. Hamilton Ave., San Jose, CA 95125, (408) 559–7778.

Founded: February 1984.

Questek:
PRECISION LASERS WITH IMPROVED POWER

The shorter a laser beam's wavelength, the more precisely the beam can be focused. Thus lasers that produce ultraviolet light should theoretically be the best tools for delicate tasks in microsurgery and microelectronics. Until recently, though, ultraviolet lasers, which produce their beams with electrically excited gases, have lacked the consistent high power necessary for these applications; it simply hasn't been possible to keep enough gas moving past a sufficiently high charge. To overcome the problem, Questek has designed a microprocessor-based laser control system to regulate the electric charge and automate gas flow. The company is only one of several—including Lambda Physik and Helionetics—developing high-powered ultraviolet excimer lasers. Questek also has an older product line of CO_2 lasers used for coded marking of electronic products.

Financing: $2.45 million in venture capital financing from Newport, a supplier of optical components, and EG&G, a manufacturer of microelectronics production equipment.

Management: Founders Gary Klauminzer (president), James Campbell (VP of marketing), and S. Spencer Merz (VP of engineering), worked together at Lambda Physic, the U.S. arm of German-based Lambda Physik. Klauminzer was Lambda Physic's president, Campbell was a product manager, and Merz was a consultant who also worked on the technical staff of EG&G.

Location: 44 Manning Rd., Billerica, MA 01821, (617) 667–6790.

Founded: October 1982.

Integrated Genetics:
BIOTECHNOLOGY FOR HEALTHCARE

Products based on recombinant DNA technology are finally beginning to emerge from the regulatory labyrinth into the healthcare market. Integrated Genetics has commercially introduced a product—a test for salmonella bacteria—for the food-processing industry, and has developed a number of other substances, both diagnostic and pharmaceutical, currently undergoing clinical trials for FDA approval. Diagnostic projects include tests for hepatitis B virus, a human T-cell leukemia virus, and the defective gene that identifies carriers of cystic fibrosis. Pharmaceutical projects include human and bovine fertility hormones, the blood clot–dissolving protein TPA, and a vaccine for hepatitis B. Among its competitors are Enzo Biochem, a maker of a test for hepatitis B, and Damon Biotech, which makes TPA.

Financing: $7.4 million in venture capital funding, and $19 million in net proceeds from a July 1983 public stock offering of 1.6 million shares. The OTC stock symbol is INGN.

Management: The company was founded by microbiologists David Housman of MIT, Bernard Forget of Yale, James Grusella of Harvard Medical School and Massachusetts General Hospital, and Arthur Skoultchi of Albert Einstein College of Medicine. Robert Carpenter, chairman, president, and CEO, was president of the Fenwal division of Baxter Travenol Laboratories. Patrick Connoy, VP of sales and marketing, was a VP of the Pharmaseal division of American Hospital Supply. Stanley Erck, VP of corporate development, was president of Combined Resources, a supplier of blood derivatives.

Location: 31 New York Ave., Framingham, MA 01701, (617) 875–1336.

Founded: April 1981.

ACQUISITION FEVER GRIPS SOFTWARE FIRMS

Small companies in a competitive field need a fast route to diversification

Software and computer service firms have been among the strongest proponents of growth based on mergers and acquisitions. Since 1981, the acquisition rate by such companies has grown 20% a year, reaching 200 acquisitions completed in 1985 at a cost of $2.6 billion. And there is no letup in sight, according to Broadview Associates (Fort Lee, N.J.).

The drive toward acquisition in the software industry is fueled by the fact that marketing costs comprise mostly training and salary of salespeople and maintenance of field offices; the cost of producing for-sale copies of a software product, once it is written, is relatively small. Thus companies able to establish a nationwide sales organization can earn high incremental profits from software that is marketed aggressively.

While a firm might carry out product and sales-office diversification on its own, acquiring other companies can be a speedier and less risky way of accomplishing the same ends. Acquisitions can also be a way to add skilled employees to a firm, and to increase its customer base.

Other sectors, such as retail stores and the hospital care industry, have also followed a growth-through-acquisitions policy. In the software market, however, the pace of acquisition is more intense because of the larger number of small firms, the higher rate of product introductions, and the greater emphasis placed on technological change.

Among the larger firms in the industry that have employed this strategy are Dun & Bradstreet, Automatic Data Processing, Computer Sciences, and Electronic Data Systems (before it was acquired by General Motors in 1984). Three smaller firms that have recently reaped the benefits of acquisitions are Computer Task Group (Buffalo), Computer Associates International (Jericho, N.Y.), and Information Resources (Chicago).

Computer Task Group (OTC: CTSK) provides customized programming, systems analysis, design, and implementation services for airline reservation, process control, and other complex systems. CTG's strategy over the past few years has been to expand its branch operations nationally by acquiring small, geographically dispersed firms. Recently, however, the firm has turned to product-oriented acquisitions. With the purchase of Dataware, for example, CTG obtained a product line of software conversion tools it can use to complete its large-scale design jobs more quickly. In addition to bringing new products to CTG, Dataware has had a joint marketing arrangement with Cullinet that will also benefit the parent firm. Because Cullinet's database management systems and CTG's systems-design services complement one another, each company can recommend the other's products to its customers, when relevant.

Acquisitions can add skilled employees to a firm overnight.

Sales for Computer Task Group were $82.9 million in 1984, with profits of $2.1 million and earnings per share of 68¢. Last year, sales increased to $115.7 million; the company made $4 million in profits and earned $1.02 per share.

Computer Associates International (OTC: CASI) is a leading supplier of tape backup, disk allocation, and other utility software products for IBM mainframes. The firm has purchased four to six small companies in each of the past four years in an effort to build a broad national sales and service organization, bolster its mainframe offerings, and expand its product line into microcomputers. Acquiring Johnson Systems, for example, has enabled CAI to provide its sales staff with some of the leading products for monitoring mainframe utilization (needed to allocate internal charges for such use). With Sorcim, the company gained access to a range of productivity software that can be marketed to the parent firm's personal computer customers; this connection helped Sorcim win a contract to supply General Electric with its products.

Sales in 1985 were $170 million, up from $116 million in 1984; profits were $16.8 million, yielding $1.55 earnings per share in 1985, in contrast to $12.2 million in profits and earnings per share of $1.13 the previous year.

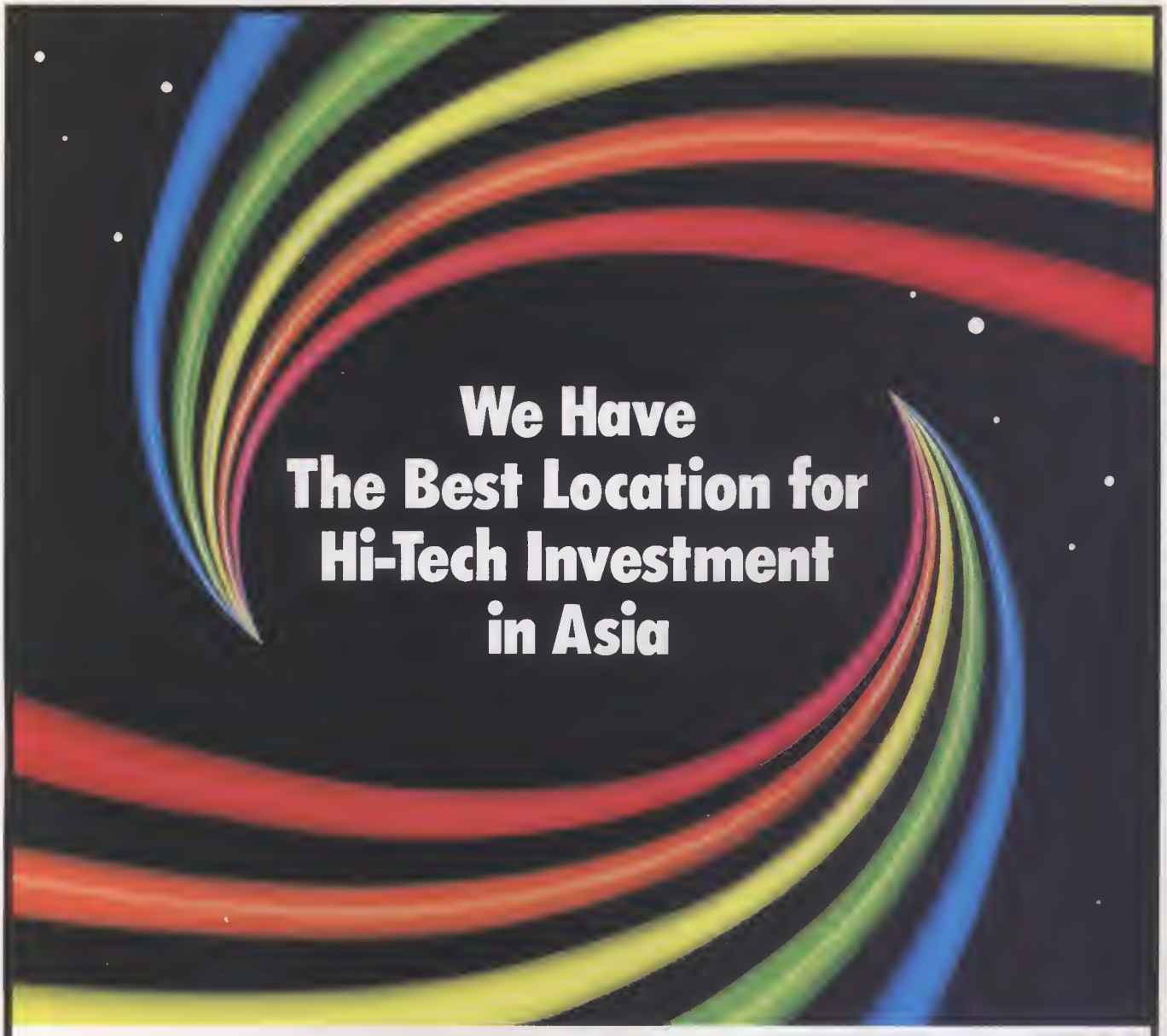
Information Resources (OTC: IRIC) has developed a proprietary database system used by packaged goods firms such as General Mills and Proctor & Gamble to test and evaluate marketing plans. By collecting data from Universal Product Code scanners at supermarkets, the company correlates spot testing of TV commercials with subsequent purchases of certain products.

In a merger of equals, Information Resources acquired Management Decision Systems (MDS) last year for $38.5 million. MDS brings to the parent firm a pool of specialized talent that will double the size of its professional staff, along with customers in consumer goods areas such as pharmaceuticals who were not previously part of Information Resources' clientele. Moreover, Information Resources expects that MDS's statistical analysis software can be used to provide better market research data to its customers.

Sales rose from $61 million in 1984 to $75 million in 1985, partly as a result of the merger. Profits and earnings per share similarly increased from $5.9 million and 55¢, respectively, in 1984 to $8.7 million and 80¢ in 1985. □

by Edward Metz and John Dexheimer

Edward Metz is a partner and John Dexheimer is an associate in Broadview Associates (Fort Lee, N.J.), a firm specializing in information industry mergers and investments.



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